Fundamentals of FINGERPRINT ANALYSIS

SECOND EDITION

Hillary Moses Daluz

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Fundamentals of Fingerprint Analysis

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This work is dedicated to

Susan Moses

My first editor, my mom, my friend

and

Norberto Daluz

My husband and greatest advocate

And to the memory of

Kathy Higgins

A beloved colleague and friend

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Preface

Science is dynamic. Over the past 25 years, the science of fingerprint analysis has experienced a number of significant paradigm shifts. Landmark publications and judicial decisions have resulted in an increase in academic and scientific rigor. The second edition of *Fundamentals of Fingerprint Analysis* updates the first edition with the most current scientific research, trends, and emerging technologies.

The innovative first edition of *Fundamentals of Fingerprint Analysis* conveyed all aspects of fingerprint theory, investigation, processing, comparison, and research. The text is currently used not only as a collegiate-level textbook, but also as a professional reference in local, state, federal and private law enforcement agencies, and forensics laboratories worldwide.

The second edition of *Fundamentals of Fingerprint Analysis* embraces international scientific advances inspired by recent developments in the forensic sciences. Fingerprint scientists can no longer lean on terms such as "uniqueness" and "permanence" without scientific justification. Conclusions can no longer be expressed in absolute terms. It is the responsibility of all forensic scientists to educate themselves and stay current on legal and scientific developments in the field. This edition addresses these issues and expands on such subjects including human factors affecting the comparison process, the development of statistical models, advancements in chemical fingerprint development, terminology, and standardization within the field and transparency in the comparison process.

This text utilizes American terminology and colloquialisms; however, it is intended for an international audience. The word "print" refers to any evidentiary friction ridge impression. This may be a palm print, fingerprint, or any other area of friction ridge skin. What is known as a "fingerprint" in the United States is referred to as a "fingermark" or "mark" throughout Europe and elsewhere in the world. "Record" prints—also referred to as exemplars or known prints—are prints that originate from a known source, such as inked prints taken on a tenprint card. A latent print "identification" is the determination that an evidentiary print and a record print may have originated from the same source.

Similarly, friction ridge development techniques vary from country to country. The decisions a fingerprint analyst makes when it comes to selection and sequence of chemical reagents are region dependent. A technique that works well in Virginia may not work, or be available, in the United Kingdom, and vice versa. Atmospheric and laboratory conditions such as temperature, pressure, and humidity, as well as storage and handling, can affect the success of a particular reagent. Wherever possible, international research is presented and discussed.

The second edition of the accompanying laboratory manual entitled *Fingerprint Analysis Laboratory Workbook* is intended to enhance the topics addressed in the textbook. The textbook chapters align with the laboratory exercises. The laboratory exercises, introductory materials, and post-laboratory questions give students hands-on experience and supplemental information that enhances comprehension.

Both editions include teaching tools not found in other professional forensics texts such as case studies, chapter review questions, chapter summaries, and introductory scientific material. They also incorporate optional instructor materials such as PowerPoint lectures for each chapter, a bank of test questions for each chapter, answers to review questions, and other useful teaching tools that are beneficial to forensic science students and professionals, criminal justice professionals, attorneys, and laypersons.

I trust the second edition of *Fundamentals of Fingerprint Analysis* will benefit forensic scientists, college students, legal experts, and law enforcement professionals as much as authoring it has furthered my professional development.

Foreword

Hillary Moses Daluz is one of the most talented, thought-provoking fingerprint experts I've ever met. Her concise and understandable presentation during lectures is well organized, interesting, and challenging. Her capabilities as an accomplished forensic science author are well represented in this second edition of her book, *Fundamentals of Fingerprint Analysis*.

Most accomplished scientists have specialty niches. Hillary's niche is teaching about fingerprints in a manner with enough clarity for laypersons to grasp, but with sufficient depth and detail to improve the knowledge of seasoned experts.

Fingerprint instructors, university students, and latent print examiner interns will appreciate how the 19 chapters in this book are logically arranged in three parts involving *Introduction*, *Processing*, and *Analysis*. Each chapter is presented in a logical format including key terms, learning objectives, individual topic subsections, review questions, and references.

I first met Hillary several years ago at an international forensic science conference where she was presenting. She explained that she had worked in a local government and federal law enforcement/intelligence community positions, including overseas duty. Hillary's employment history includes more fingerprint detection and harvesting duties than most budding latent print examiners have the opportunity to experience. I had heard she was a lively and interesting speaker, and she did not disappoint me, or the audience.

Fundamentals of Fingerprint Analysis, Second Edition, is an excellent book for readers seeking to learn the many steps involved in harvesting, documenting, evaluating, comparing, and communicating friction ridge analysis evidence.

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Thank you to my editor, Mark Listewnik; thank you for spearheading this project and working tirelessly to promote my books. Thank you also to Misha Kydd for answering dozens of questions during the writing process.

I am honored to have had a distinguished group of colleague proofreaders as a part of this project's first edition: Ken Moses, Robert Ramotowski, Robert Gaensslen, Mike Stapleton, Mark Hawthorne, Wilson Sullivan, David Burow, Kathy and Peter Higgins, Kasey Wertheim, Kimberlee Sue Moran, Helen Gourley, Malory Green, David Haymer, and Ron Smith.

Thank you to the colleagues who have mentored, educated, and inspired me, especially John Thornton, Peter Higgins, and the members of the California State Division of the International Association for Identification who nurtured my career from its inception.

Finally, I would like to acknowledge my colleagues worldwide—many deployed to battlefield environments—working tirelessly to make our communities safer places to live.

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About the Author

Hillary Moses Daluz is an instructor for Tri Tech Forensics and a Forensic Specialist with Forensic Identification Services. Daluz began her career as a Police Identification Specialist with the City of Hayward Police Department in Hayward, California. After earning her Masters of Science degree in Forensic Science from the University of California, Davis, she deployed to the Joint Expeditionary Forensic Facility at Camp Victory in Baghdad, Iraq as a Latent Print Examiner. After returning stateside she became a member of the faculty in the Forensic Sciences program at Chaminade University of Honolulu, teaching at the undergraduate and graduate levels. She then accepted a position as a Senior Latent Print Technician with American Systems. Daluz is a member of the Board of Directors for the International Association for Identification.

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I

Introduction to Fingerprints

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Introduction

1

> Let no one despise the ridges on account of their smallness, for they are in some respects the most important of all anthropological data. We shall see that they form patterns considerable in size and curious variety in shape, which are little worlds in themselves.
>
> **Sir Francis Galton**[1]

LEARNING OBJECTIVES

- Understand the goal of forensic science.
- Identify the three facets of forensic investigations.
- Describe how professional and personal integrity are critical to the forensic scientist.
- Understand class and individual characteristics.
- Name the fingerprint pattern types and minutiae.
- Explain the two premises of fingerprint identification.

1.1 Friction Ridges

A fingerprint, or fingermark, is a raised area of minute ridges found on the surface of the skin of each finger. These structures are known as friction ridges. Friction ridges are found not only on the fingers but also on the palms of the hand and on the soles of the feet. The Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST) defines a friction ridge as "a raised portion of the epidermis on the palmar or plantar skin, consisting of one or more connected ridge units."[2] The word "palmer" refers to the hand: the palms of the hands, finger joints, and fingertips. The word "plantar" refers to the bottoms of the feet and the toes.

Friction ridges are similar in contour to mountain ranges. Just as mountains are pushed up through the earth's crust to the surface, so too are friction ridges pushed up through the layers of the epidermis to the skin's surface. Though friction ridges all appear to be of the same width and height when viewed under minimal magnification, they are in fact extremely variable. Friction ridges vary in width, height, and contour. They are punctuated with sweat pores that also vary in size and contour.

The evolutionary function of the friction ridges is in the word "friction." In Physics, friction is the measure of resistance when the surfaces of two objects are pressed together or when two objects move against each other. An example is the friction of automobile tires. When the break is applied with force, the rubber of the tires may leave skid marks on the road. Another example of friction is the action of scraping a wooden surface with sandpaper. The rougher the surface, the more friction is created between two objects.

We use our hands to grip objects throughout our daily lives. We turn doorknobs, drink from glasses, type on keyboards, drive vehicles, and write with pens. Our friction ridges allow us to perform all of these tasks. If we did not have friction ridges on our fingers, we could not easily grip a smooth drinking glass or a mobile phone. Friction ridges create a rough, textured surface that provides resistance between our hands and anything we touch (Figure 1.1).

Friction ridges formed over thousands of years of evolutionary development. They are found not only on human hands and feet but also on the hands, feet (Figure 1.2), and prehensile tails (Figure 1.3) of other primates. This was addressed in a thesis written by Johannes Purkinje, a Czech scientist who contributed extensively not only to the science of fingerprint analysis but also to physics and physiology.[3] His 1823 thesis entitled *Commentatio de examine physiologico organi visus et systematis cutanei* (A physiological examination of the visual organ and of the cutaneous system) describes not only the presence of friction ridges in primates but also the presence of distinctive pattern types.[4]

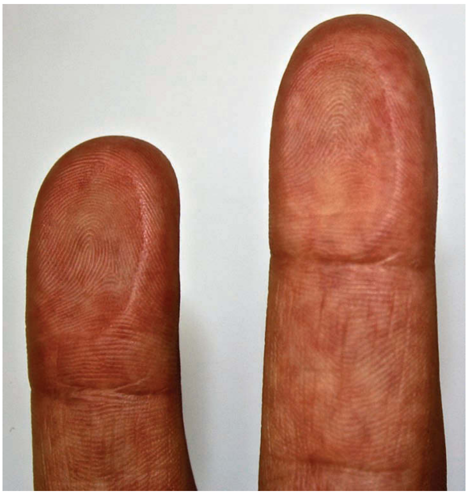


Figure 1.1 Friction ridges against a glass surface.

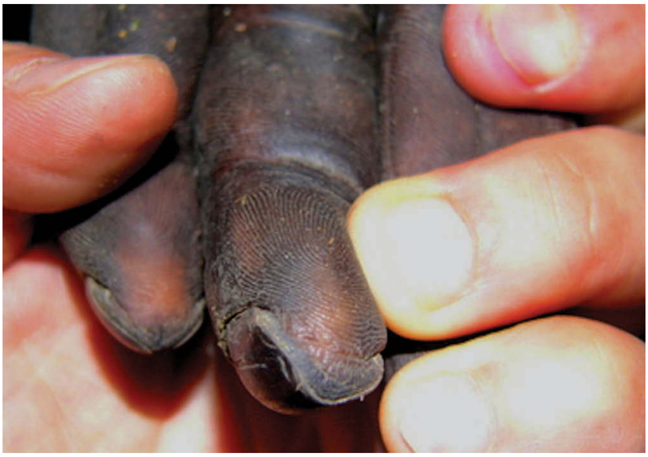


Figure 1.2 Chimpanzee fingerprints.

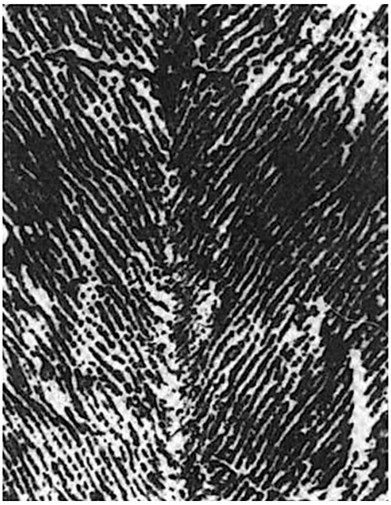


Figure 1.3 Friction ridges on the prehensile tail of a monkey (1829).

Each fingerprint consists of a distinct pattern of friction ridges and dozens of minute characteristics. Latent print examiners and tenprint examiners utilize these patterns, locations, and types of characteristics, and other information from the friction ridges in order to determine whether impressions of unknown origin and impressions of known origin may come from the same source.

1.2 The Forensic Sciences

Fingerprints are used to determine identity in the banking and financial services industry, border security, vehicle registration, military records, and many other applications and industries. This text focuses on the use of friction ridge impressions in the forensic sciences. The word *forensic* comes from the Latin word *forensis*, which means "of the forum." In ancient Rome, the forum, or marketplace, was the center of civic life. Civil and criminal cases were heard in public before an assemblage at the forum. Each adversarial side would proffer a legal argument in oratory form. The forum was essentially a court, though not in the sense we would imagine a courtroom today.

Modern day forensic science refers to any science applied to legal matters (Figure 1.4). There are many subdisciplines of forensic sciences, but all apply the topic at hand to matters of law. For example, forensic anthropology is the study of decomposed or skeletonized

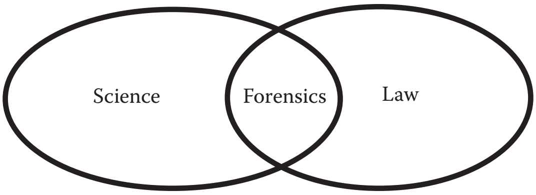


Figure 1.4 Forensic science is the intersection between science and the law.

remains as it applies to matters of the law. Forensic entomology is the study of arthropods—insects and spiders—as it applies to legal matters. "Legal matters" refer to crimes or prospective crimes as well as civil disputes.

Legal matters are decided in a court of law. Courtroom testimony is a critical final step in the analysis of forensic evidence, whether that evidence is bones, insects, or fingerprints. During this process, forensic scientists explain their professional qualifications, the scientific analyses performed for the case at hand, any opinions generated from those analyses, and the science behind them.

Explaining the science to a jury is often the most challenging part of the testimonial process. The forensic scientist may also be asked to recount the history, theory, research and investigative methods, and relevant court cases pertaining to the science. In these respects, the successful forensic expert witness is an effective teacher. See Chapter 18 for more on this topic.

1.3 Fingerprints as Forensic Evidence

Fingerprint analysis is one of the most common and historically consistent subdisciplines of the forensic sciences. For over 100 years, latent prints have been used to identify individuals in the criminal justice system. Fingerprint records are collected from suspected criminals following an arrest. These records, which can be either in a digital or paper cardstock format, are compared to prior arrest records and unidentified evidentiary fingerprints. Evidentiary fingerprints are those developed at crime scenes and in crime laboratories using fingerprint powders, forensic light sources, and chemical processing methods. Fingerprints have been used to solve countless crimes over the course of history. Every day, thousands of fingerprint examiners all over the world make fingerprint comparisons that contribute to criminal and civil investigations.

There are three major facets of forensic science: (1) to demonstrate whether or not a crime has been committed; (2) to identify the individuals involved and how those individuals are associated with other individuals and the crime scene; and (3) to reconstruct the crime scene and the sequence of events that occurred. Fingerprints may be used throughout these processes to provide investigative leads. Figure 1.5 illustrates the evidence linkage triangle, a common pictorial representation of the link between the crime scene, victim, and suspect (Figure 1.5). There may be more than one suspect, victim, or even crime scene.

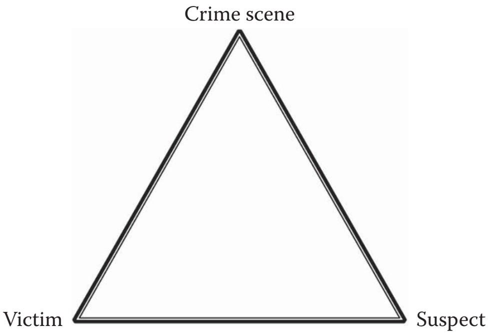


Figure 1.5 The evidence linkage triangle demonstrates the link between the crime scene, victim, and suspect.

Fingerprints can link a victim to a crime scene, a suspect to a crime scene, and/or a suspect to a victim.

Fingerprints not only provide investigative leads but also are evidence in themselves. Gardner defines evidence as "anything that tends to prove or disprove a fact in contention."[4] There are two types of evidence: testimonial and physical. Testimonial evidence refers to verbal accounts such as eyewitness statements or transcripts of interviews. This type of evidence is subjective, meaning it is subject to either intentional or unintentional biases of the individual. Physical evidence includes both physical evidentiary items such as weapons and bloody clothing and forensic evidence such as fingerprints, trace evidence, and DNA.

A scientist must be conscious of bias at all times. The key to an impartial forensic examination is an awareness of the potential sources of bias as well as a focus on integrity: recognizing that everyone has inherent biases and consciously pushing those biases aside. Integrity is defined by the Merriam-Webster dictionary as "firm adherence to a code of especially moral or artistic values."[5] It also relates the word integrity to "completeness," "soundness," and "incorruptibility."[5] In the discipline of forensic sciences, your personal and professional integrity must be compatible and irrefutable.

1.4 Fingerprint Analysis

Fingerprint evidence is valuable because fingerprints are biologically distinct. No two fingerprints have been found to share the same types and arrangements of distinct, minute characteristics alluded to in Section 1.1. Consequently, fingerprint examiners can use those characteristics to determine whether questioned evidentiary fingerprints and known record prints likely originated from the same source. The process to accomplish this is known as fingerprint analysis or fingerprint comparison. Fingerprint comparison is the act of determining whether two friction ridge impressions can be associated. Fingerprint examiners compare unknown fingerprints from crime scenes or items of evidence to known fingerprints and make a determination as to the source of the prints.

There are two types of structural characteristics within the friction ridge impressions that allow fingerprint examiners to compare fingerprints and make source attributions: pattern types and minutiae. Pattern types—arches, loops, and whorls—are not unique to the individual. They are class characteristics. Class characteristics are features that place an individual or object in a group or category. For example, hair color is a class characteristic. A group of 100 individuals could be grouped into smaller categories, or classes, based on hair color.

Minutiae (pronounced mi-noo-shuh) are individualizing characteristics. Individualizing characteristics are those features that are unique to one particular person or thing. Expanding on the previous example of hair color as a class characteristic, the DNA contained in each individual hair is an individualizing characteristic. Just as no two individuals have been found to have identical fingerprints, similarly no two individuals have been found to have identical DNA profiles. Fingerprint examiners analyze both the class characteristics and individualizing characteristics of fingerprints in order to reach a conclusion.

Class and individual characteristics are used to describe many forensic evidentiary items such as shoeprints, tire tracks, biological evidence, and firearms evidence. Examples of class and individual characteristics are observable everywhere. For example, a suitcase may demonstrate both class and individualizing characteristics. The class characteristics include the following features: size, shape, presence or absence of wheels, color, fabric, number of zippered pockets, and number of zippers. Imagine your suitcase is a red, nylon carry-on suitcase with three zippered pockets and wheels. You check your bag with the airline and expect to identify it on the baggage carousel when you reach your destination. If there are hundreds of suitcases on a revolving luggage carousel, you will need to observe the class and individual characteristics to determine which bag belongs to you. Each class characteristic narrows down the number of possibilities. Perhaps you will first look for suitcases that are red and then examine the size of each suitcase, then perhaps the presence or absence of wheels.

But what if there is another suitcase that looks just like yours? What individualizing characteristics can you use to distinguish your suitcase from its apparent twin? Unique characteristics accumulate on physical items with use. A suitcase might have a tear in the fabric, a dent, a loose wheel, or a missing zipper. These are individualizing characteristics that may help you identify your suitcase. You may have placed individual characteristics on your bag intentionally by attaching a unique patterned ribbon to the handle or a luggage tag containing your name and contact information.

The human brain identifies an object or person in a natural progression from recognizing class characteristics to confirmation by individualizing characteristics. You may not be able to read your luggage tag while your suitcase is coming around the conveyer belt, but you can certainly observe the sizes, colors, and styles of the suitcases as they approach to narrow down the possibilities. When the bag gets close enough for a more rigorous examination of its individualizing characteristics, you can then conclusively determine which bag is yours.

Fingerprint pattern types are class characteristics and are therefore used to narrow down the potential field of candidates who may be the source of the fingerprint in question, just like the color and size of a suitcase narrow down the possibility that suitcase belongs to you. There are three categories of fingerprint patterns: arch, loop, and whorl (Figure 1.6). There are eight sub-pattern types within these categories: ulnar loop, radial loop, plain whorl, double-loop whorl, central pocket loop whorl, accidental, plain arch, and tented arch (Figure 1.7). Other class characteristics of friction ridge impressions include the presence of creases and scars, the ridge count of a loop, and the tracing of a whorl pattern. These characteristics will be discussed in detail in Chapter 4.

The friction ridges that make up an impression are not continuous, as they may appear at first glance. A ridge may end abruptly, split into two (or three) ridges, or form other structural features dependent on the ridge flow within the impression. These individualizing characteristics are known as minutiae. In order to reach a conclusion, a fingerprint

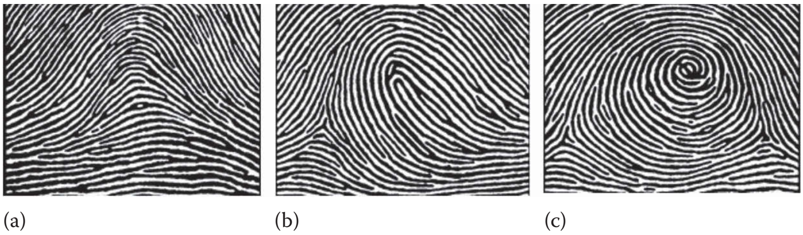

(a) (b) (c)

Figure 1.6 The three basic fingerprint pattern types: arches, loops, and whorls.

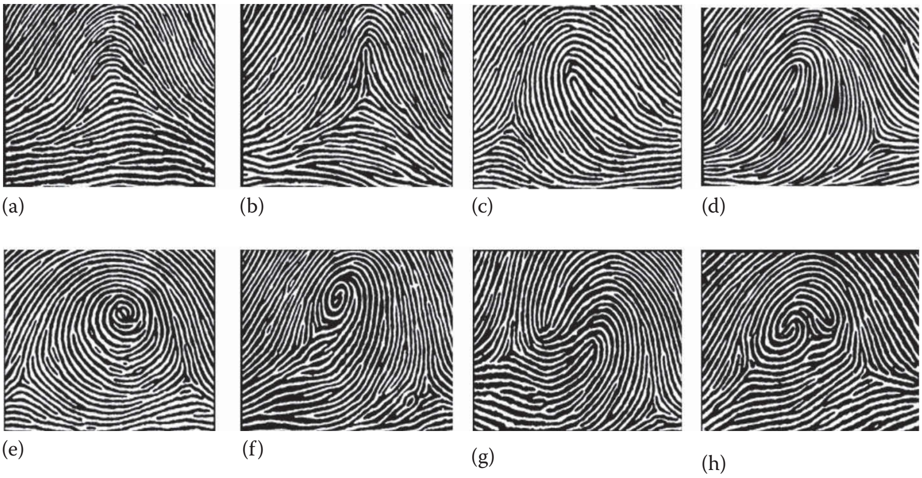

(a) (b) (c) (d)
(e) (f) (g) (h)

Figure 1.7 The eight fingerprint sub-pattern types: plain arch, tented arch, right-slanted loop, left-slanted loop, plain whorl, central pocket loop whorl, double-loop whorl, and accidental whorl.

examiner must analyze and compare the minutiae. As the name implies, minutiae are only clearly visible with magnification due to their minute size.

There are three types of minutiae: bifurcations, ending ridges, and dots (Figure 1.8). A bifurcation occurs when one friction ridge splits into two friction ridges similar to a fork in a road. A friction ridge may come to an abrupt end, forming an ending ridge. A friction ridge may be short, rather than continuous, with an ending ridge on each end. This is known as a short ridge. The third type of minutiae is the dot, which appears—true to its name—as a dot between two friction ridges. It is the shortest possible ridge as it is

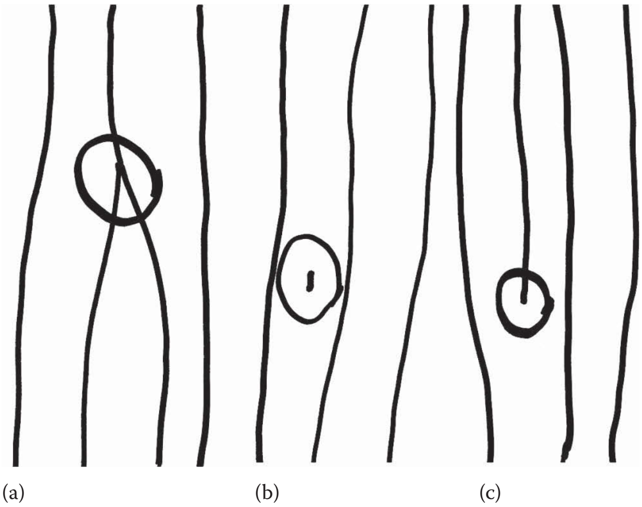

(a) (b) (c)

Figure 1.8 A line drawing of a bifurcation, dot, and ending ridge.

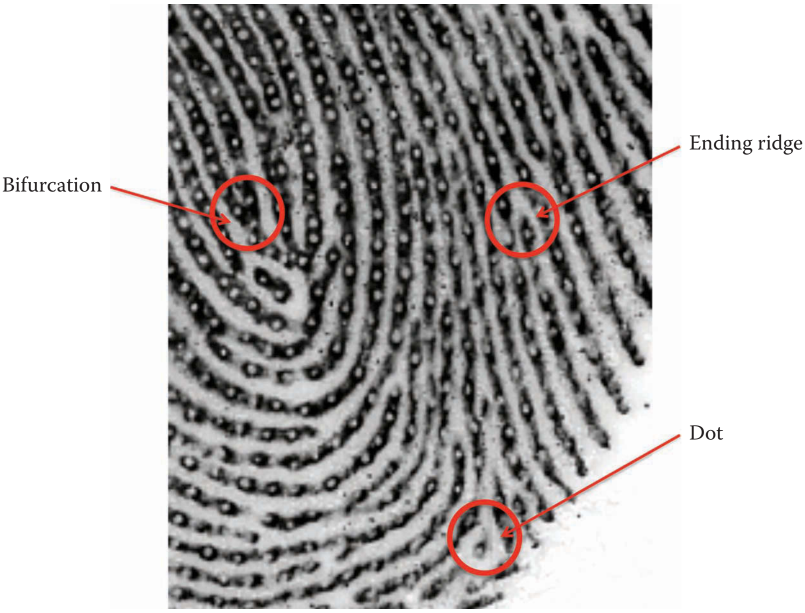


Figure 1.9 A bifurcation, dot, and ending ridge in a magnified portion of a fingerprint.

composed of one friction ridge unit (Figure 1.9). Minutiae are best observed under magnification. The standard fingerprint magnifier has 3× to 5× magnification, which allows the fingerprint examiner to compare unknown, evidentiary prints to known record fingerprints (Figure 1.10).

There are three possible conclusions to a fingerprint analysis and comparison: identification, exclusion, or inconclusive. The conclusion reached by a fingerprint examiner is an opinion based on the information in the fingerprints coupled with the examiner's knowledge, training, and experience. An *identification* conclusion indicates that, in the opinion of the examiner, there are enough features in agreement between the evidentiary

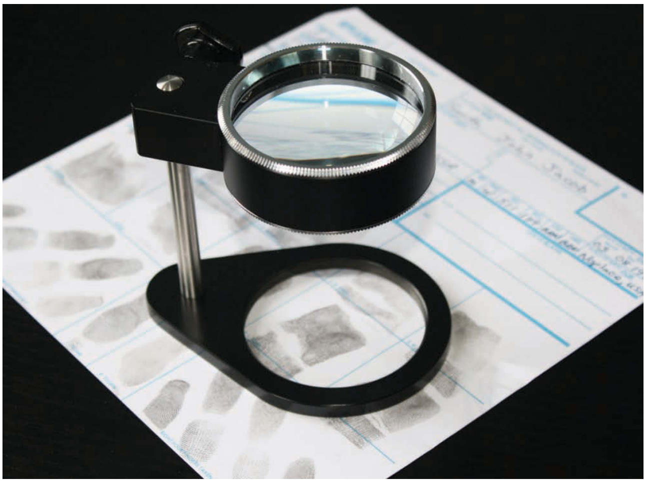
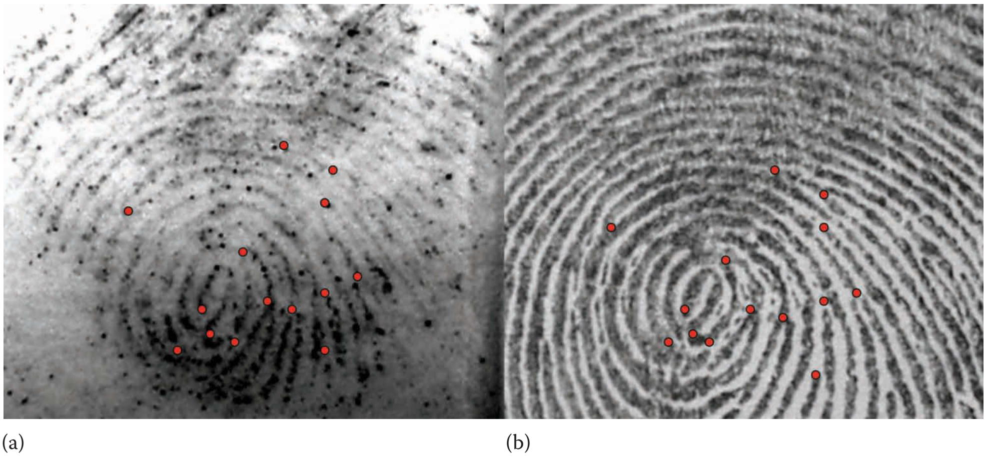


Figure 1.10 A fingerprint magnifier, also known as a loupe.



(a) (b)

Figure 1.11 A fingerprint that has been identified to a suspect. The fingerprint on the left is a latent fingerprint from a crime scene. The fingerprint on the right is the left thumbprint of the suspect.

print and record print to conclude that both prints likely originate from the same source (Figure 1.11). The term "individualization" has also been used to indicate an identification conclusion.[6]

An *exclusion* is appropriate when the same corresponding areas of two friction ridge impressions are incompatible. In the opinion of the examiner, there are enough features in disagreement between the evidentiary print and record print to conclude that both prints likely originate from different sources. An analysis of pattern type alone can lead to an exclusion conclusion. For example, if the evidentiary print is clearly an arch pattern, but the recorded fingerprints display only loops and whorls, that individual can be excluded as the source of the evidentiary print.

An inconclusive result is reached when a fingerprint can neither be conclusively identified nor eliminated. This can happen if the evidentiary print is from an anatomical area not recorded in the record fingerprints. It can also occur if the record prints are not of good enough quality to use as exemplars. Fingerprint comparisons will be discussed in detail in Chapter 16.

1.5 Uniqueness and Persistence

Historically, two main premises have formed the basis for the science of fingerprint identification:

1. Fingerprints are unique.
2. Fingerprints are persistent.

The concept of uniqueness infers that there are likely no two people in the world with the same fingerprints. Even identical twins with identical DNA profiles have different fingerprints. This concept could never be proven absolutely since it would be impossible to compare every fingerprint in the world with every other fingerprint in the world. Fingerprint analysis was built on the premise of uniqueness because of the observed randomness of natural processes.

The concept of persistence—previously referred to as permanence—indicates that the arrangement of friction ridges, including minutiae and pattern types, do not change throughout your lifetime. They form in utero in the deepest layer of the epidermis and do not change with age. The only changes that may occur over time are the wearing of the friction ridges due to age or manual labor or the formation of scars due to injury.

This text explores the science of fingerprint analysis in every context. It first addresses the background, theory, and history of the science of fingerprint identification; followed by a discussion of the development, visualization, and documentation of latent fingerprints from evidence and crime scenes; and finally, fingerprint comparisons and courtroom testimony.

1.6 I Had a Case: Questionable Pattern Types

In rare cases, a fingerprint analyst will encounter an unusual pattern type that is difficult to categorize. The fingerprint in Figure 1.12 appears, at first glance, to be a whorl pattern (Figure 1.12). The friction ridges in the center of the pattern make a complete circle around the core. However, underneath that core is an upside-down loop. It was important, in this case, for the fingerprint examiner to determine that this pattern is not a whorl, but an accidental.

1.7 Chapter Summary

Fingerprints, palm prints, and footprints are patterns made by friction ridges, which are raised portions of the epidermis found on the hands and feet. Friction ridges are the result

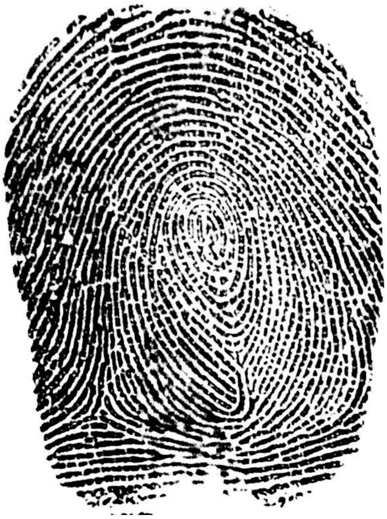


Figure 1.12 An accidental whorl pattern. (Reprinted with permission from Siegel, S. 2017. Back to basics: dactylography – Questionable unusual interesting pattern. *J. Forensic Identif.* 67(2): pp. 304. Image submitted by Diane Donnelly, Indianapolis-Marion County Forensic Services Agency.)

of evolutionary development. The ridges create a textured surface that allows humans and other higher primates to grip objects. Forensic science refers to any science applied to legal matters. Forensic scientists testify to their processes, conclusions, and opinions in a court of law. Fingerprints have been used as forensic evidence for over 100 years. Evidentiary friction ridge impressions from crime scenes and items of evidence are compared with record fingerprints from known individuals. A fingerprint comparison results in one of three conclusions: identification, exclusion, or inconclusive. Fingerprints are valuable as forensic evidence because they are unique and persistent, though uniqueness cannot be proven in absolute terms.

1.8 Review Questions

1. What are friction ridges?
2. Why do we have friction ridges on our hands and feet?
3. Define “forensic science.”
4. What are the three facets of forensic science investigations?
5. Why is integrity an important quality for a forensic scientist?
6. What are the eight types of fingerprint patterns?
7. What are the three types of minutiae?
8. What class characteristics do we see in fingerprint impressions?
9. What individualizing characteristics do we see in fingerprint impressions?
10. What are the three possible conclusions of a fingerprint comparison?

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History

2

> If one wants to define the future, they must study the past.
>
> **Confucius**

LEARNING OBJECTIVES

- Understand why it is important to know about history.
- Learn the key historical figures and their contributions to fingerprint analysis.
- Compare and contrast anthropometry with fingerprint identification.
- Understand the concept of fingerprint classification.
- Recognize the importance of paradigm shifts in the field.

2.1 Why Study History?

Why is a basic working knowledge of history important for the fingerprint examiner? Regardless of the subdiscipline of forensic science one chooses to practice, it is important to know the key players and events that formed the discipline. Knowing where we came from gives us a better understanding of where we are now as scientists, as well as the future of the science. What are the future capabilities of the science? What research is necessary to advance the science? If you are studying to become a forensic scientist, you are the future of the science. The most effective scientist has a solid grasp of the history and development of the science.

Most fingerprint certification tests require knowledge of the history of fingerprint identification. A certification test is a voluntary examination that tests your general knowledge, professional capabilities, and competency. The certification examinations test not only your skill level but also your background knowledge of the science, including its history. The International Association for Identification (IAI) conducts certification exams for many forensic disciplines.[1]

Finally, a working knowledge of history is important because you may be asked questions about historical figures and events while testifying in a court of law. All forensic scientists are expected to testify in court. The forensic expert may be asked any number of questions regarding a forensic investigation, not just what you did and how you did it, but the history behind the science. Are there any historical court cases, events, or figures that influenced a particular fingerprint examination? A strong working knowledge of the science and other aspects of fingerprint analysis such as those mentioned above go a long way to establishing credibility in a court of law.

2.2 Ancient History

There is plenty of evidence that ancient hominids had friction ridges on their hands and feet just as modern man and primates do. Unintentional fingerprint impressions have been recorded on ancient pottery and bricks. The earliest examples of friction ridge impressions on pottery were unearthed in China. These fragments were dated to approximately 4000 BCE.[2,3] Archaeologists speculate whether the impressions on the earthenware were toolmarks, decorative, intentional, or unintentional markings.

Exactly when the concept of using fingerprints for identification purposes was developed is unknown. Archaeologists have recorded instances of Middle Eastern potters "signing" their work with fingerprints impressed into clay, though these fingerprints may have been merely identifying marks rather than impressions linked to a specific individual.[3] The noted archaeologist William Frederic Bade purportedly said, "I do not for a moment believe that the potters were aware that their fingerprints had the distinctiveness which is now recognized in the fingerprint system. It is the place and the arrangement of the impressions which served as distinguishing marks to them."[4] Any symbol or mark would have served the same purpose.[4] Paleolithic bricks also display impressed fingerprint patterns. These impressions were likely "toolmarks" that had a practical use: to provide a rough surface so mortar material would better adhere to bricks. Paleolithic stones were carved with geometric shapes resembling fingerprint patterns, though there is also debate as to whether the patterns were intentionally formed to mimic fingerprints (Figure 2.1).

Impressed fingerprints have been found on clay sealings from ancient Mesopotamian archaeological sites dating from 2600 to 2350 BCE (Figure 2.2).[5] In ancient Babylonia, fingerprints were impressed into clay tablet contracts from 1913 to 1855 BCE.[2] Fingerprints were used as identifying marks in ancient China during the Qin and Han dynasties as

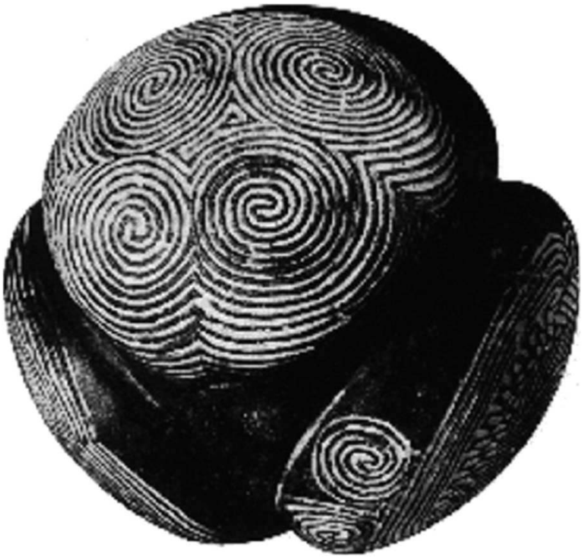


Figure 2.1 A Scottish carved stone ball known as a "petrosphere" is decorated with designs resembling fingerprint patterns. (Retrieved from the website of the Ancient Wisdom Foundation, http://www.ancient-wisdom.co.uk/stoneballs.htm, accessed on 01/07/2014.)

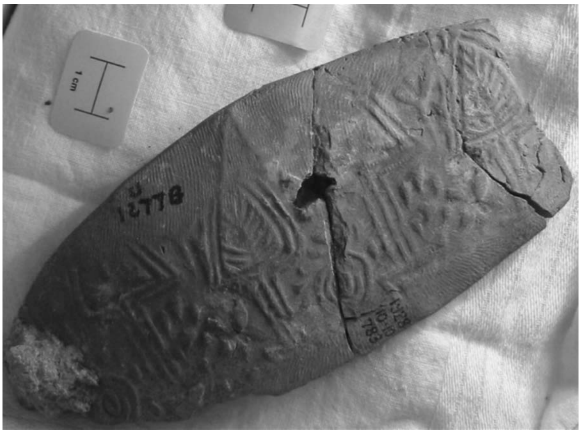


Figure 2.2 Clay sealing from the archaeological site of Ur (2600–2350 BCE). (Photo courtesy of Kimberlee Sue Moran, Director, The Center for Forensic Science Research and Education.)

early as 246 BCE.[6] Before the advent of paper, fingerprints were impressed into clay seals that bound important documents.[6] These were the ancient version of the wax seals seen in the western world hundreds of years later. In addition to a monogram or identifying mark or symbol, the Chinese used a fingerprint on the opposing side of the clay seal to further verify the author's identity and deter anyone from breaking the seal to read the contents of the document.[6] There are also examples of documents authored by the nobility in India, which were validated by fingerprints.[2,3]

Chinese dynastic history is filled with examples of fingerprints used as personal marks long before European historical fingerprint records. Besides the clay seals used during the Qin dynasty, bamboo slips (a writing medium) have also been uncovered that record how fingerprints were used in burglary crime scene investigations.[6] Throughout the Han dynasty and Six Dynasties period (206 BCE to 589 CE), the availability of paper and silk writing materials provided a new substrate for recording fingerprints.[6] Anthropometric records—records measuring the shape or dimensions of the finger or hand—were commonplace.[6] Throughout the remaining history of dynastic rule, anthropometric records and deliberately recorded friction ridges were used on the following official documents: army rosters, engagements and divorces, deeds for lands and homes, and records of indenture.[6] Fingerprints were also used as evidence in criminal and civil disputes, including recording confessions.[6]

2.3 Seventeenth to Nineteenth Centuries

The seventeenth and eighteenth centuries gave birth to the scientific revolution, a period of history characterized by major scientific breakthroughs that opened up the floodgates of scientific advancement. This was the era of Copernicus, Sir Isaac Newton, and Galileo Galilei. Newton's laws of motion and the concept of heliocentricity—the idea that the earth and other planets revolve around the sun—were being accepted as mainstream. Mathematics, chemistry, and astronomy were nascent and emerging fields in the western world.

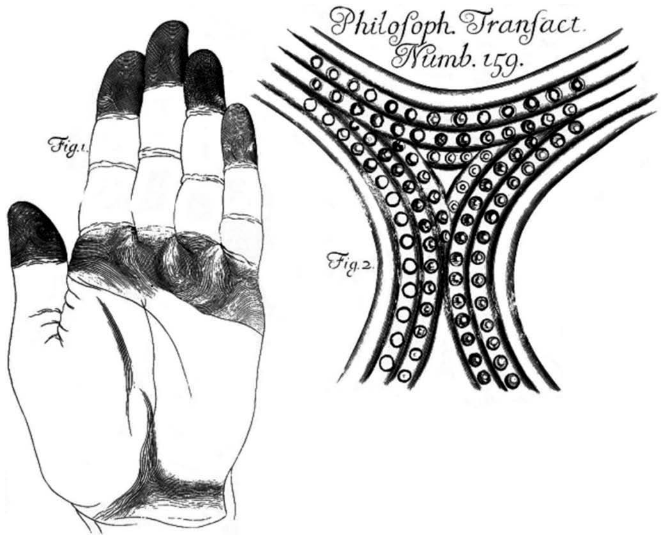


Fig.1
Philosoph. Transact.
Numb. 159.
Fig.2

Figure 2.3 Nehemiah Grew's illustrations of friction ridges and pores. (Reprinted with permission from Grew, Nehemiah, The description and use of the pores in the skin of the hands and feet, *Philosophical Transactions of the Royal Society of London*, vol. 14: p. 566.)

Nehemiah Grew, the "father of plant physiology," performed the first scientific analysis of friction ridges using the newly invented microscope.[2,3,7,8] He described terminology related to friction ridge patterns and structures.[3,8] He also described the physiological aspects of sweat pores and the placement of creases. The following is an excerpt from Grew's 1684 publication, *The Description and Use of the Pores in the Skin of the Hands and Feet*:

> For if any one will but take the pains, with an indifferent Glass, to survey the Palm of his Hand very well washed with a Ball; he may perceive… innumerable little Ridges, of equal bigness and distance, and everywhere running parallel with one another. And especially, upon the end and first Joynts of the Fingers and Thumb, upon the top of the Ball, and near the root of the Thumb a little above the Wrist. In all which places they are regularly disposed into Spherical Triangles and Ellipticks.[9]

Within this treatise, Grew not only describes but also illustrates fingerprint structures (Figure 2.3).[7] Marcello Malpighi, a contemporary of Nehemiah Grew, also published his microscopic observations of friction ridges. He was the first scientist to describe the function and evolutionary importance of friction ridges.[2]

The nineteenth century was an era of exploration and scientific curiosity. Scientists were going out into the world, making observations, and applying the scientific methodology formulated in the previous century. There was a burgeoning interest in nature and how things work. Today, scientists are specialists with narrow research concentrations, whereas in the nineteenth century, scientists were generalists who studied entire disciplines. It was common for a "naturalist" to study medicine, evolution, and the structure and function of animal and plant species. As we became more scientifically advanced as a society, scientists became more specialized. That occurrence is observed in the field of forensic sciences today. The discipline has grown from a general forensics discipline into many subdisciplines, such as fingerprint examination, serology, DNA analysis, drug chemistry, firearms and toolmarks, and toxicology.

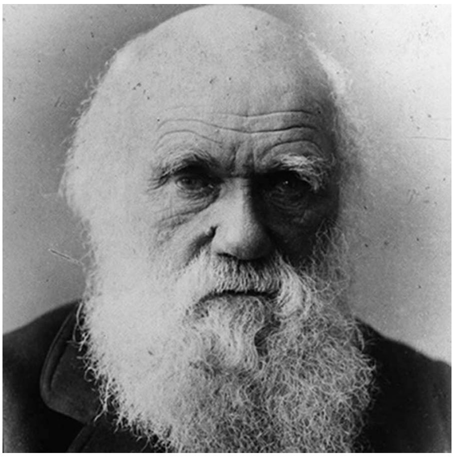
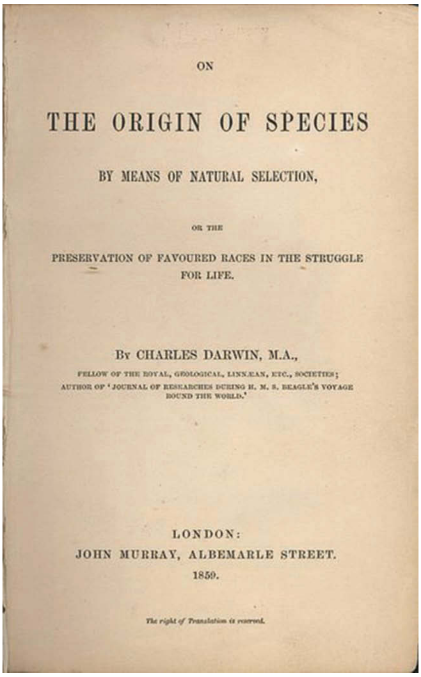


Figure 2.4 Charles Darwin.



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE
FOR LIFE.

BY CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE
ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The right of Translation is reserved.

Figure 2.5 *On the Origin of Species* was Charles Darwin's definitive work on his studies of ecology and evolution.

Major scientific theories originated in the 1800s. The noted naturalist Charles Darwin traveled the Galapagos Islands on the HMS Beagle, making observations that eventually led to his evolutionary theory of natural selection (Figure 2.4). Darwin was influenced by other great scientific minds of the century such as Charles Lyell, a geologist whose theory of "uniformitarianism" asserted that the earth was formed, and continues to be formed, by slow-moving processes.[6] Charles Lyell's publication *Principles of Geology* was as influential in its time as Charles Darwin's *On the Origin of Species*, which was published in 1859 (Figure 2.5).[10]

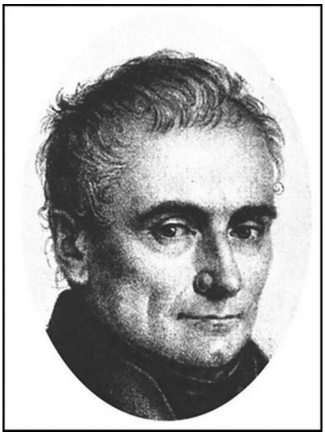


Figure 2.6 Johannes Evangelista Purkinje.

Art also played an important role in the advancement of scientific knowledge through observation. Centuries earlier, Leonardo da Vinci famously sketched and diagramed the human form as well as other scientific phenomena and feats of engineering. Prior to the advent of the camera, scientific observations were recorded in line drawings with minute attention to detail. We see this in the work of Johannes Purkinje whose line drawings of friction ridge patterns are exceptionally detailed (Figure 2.6).[8] We also see examples of biological art in the work of Thomas Bewick, a British naturalist, botanist, and author.[8] Bewick made wooden engravings of his own fingerprints in great detail. The wooden engravings were used as stamps, which he used in conjunction with his signature.[8] Bewick's attention to detail in his friction ridge engravings demonstrates a knowledge and careful observation of friction ridge structures.

The science of fingerprint analysis began to take shape in the mid-1800s in the colonies of the British Empire, specifically, in India. British administrators, doctors, scientists, and representatives went to India to perform various administrative and governing functions. Sir William Herschel was an administrator for the East India Company in the province of Bengal (Figure 2.7).[8] As a magistrate and collector, he was in charge of the courts, prison, deed registrations, and pension payments.[2,8] In India, fingerprints and handprints had been used to authenticate and sign documents for hundreds of years. Herschel continued with this practice as contracts with handprints held greater importance than those with signatures alone. As a result, he became the first British man to acknowledge the individualizing power of fingerprints.[3] Though Herschel has been credited as the first European to recognize the uniqueness of fingerprints, it was JCA Mayer of Germany who published a statement in 1788 stating, "Although the arrangement of skin ridges is never duplicated in two persons, nevertheless the similarities are closer among some individuals. In others the differences are marked, yet in spite of their peculiarities of arrangement all have a certain likeness."[3] Later in life, Herschel experimented with the concept of permanence by fingerprinting himself over a period of 50 years.[2]

Dr. Henry Faulds is another significant figure in the history of fingerprint analysis (Figure 2.8). Faulds was a medical missionary to India and Japan who studied fingerprint structures extensively. He was the first European to publish an article stating that visible fingerprints, such as bloody, greasy, or sooty fingerprints, may be useful for solving crimes.[8] This article entitled *On the Skin-Furrows of the Hand* was published in *Nature* in

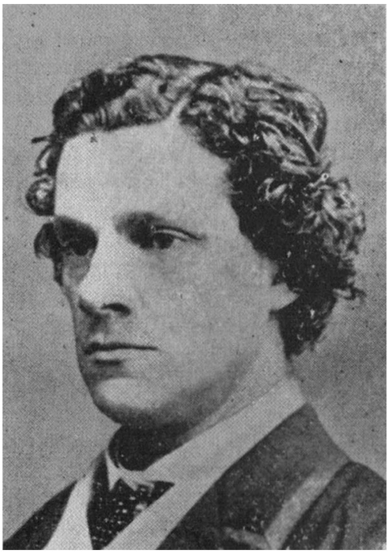


Figure 2.7 Sir William J. Herschel. (Reprinted with permission from Asbaugh, D. 1999. *Quantitative-Qualitative Friction Ridge Analysis*. Taylor & Francis: p. 21.)

1880.[11] When Faulds wrote a letter to Charles Darwin to share his observations, Darwin referred him to his cousin, Sir Francis Galton.[8]

A contemporary of Herschel and Faulds, Galton wrote the first book on fingerprints in 1892 entitled *Finger Prints*.[12] His research was based on the research of his contemporaries, as well as the historical use of fingerprints by Asian cultures. Galton described fingerprints as unique and permanent, historical premises similar to those we rely on today. He also described the minute structures within patterns called minutiae, or Galton details, which are the identifying features used in fingerprint comparisons.

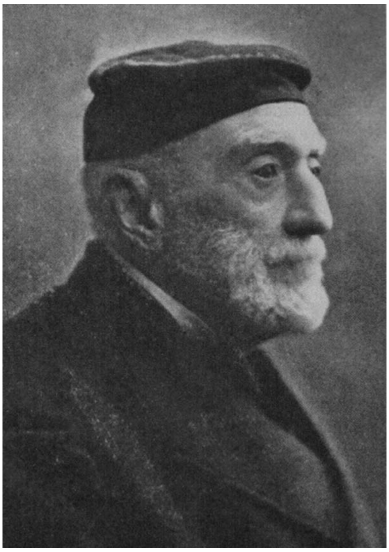
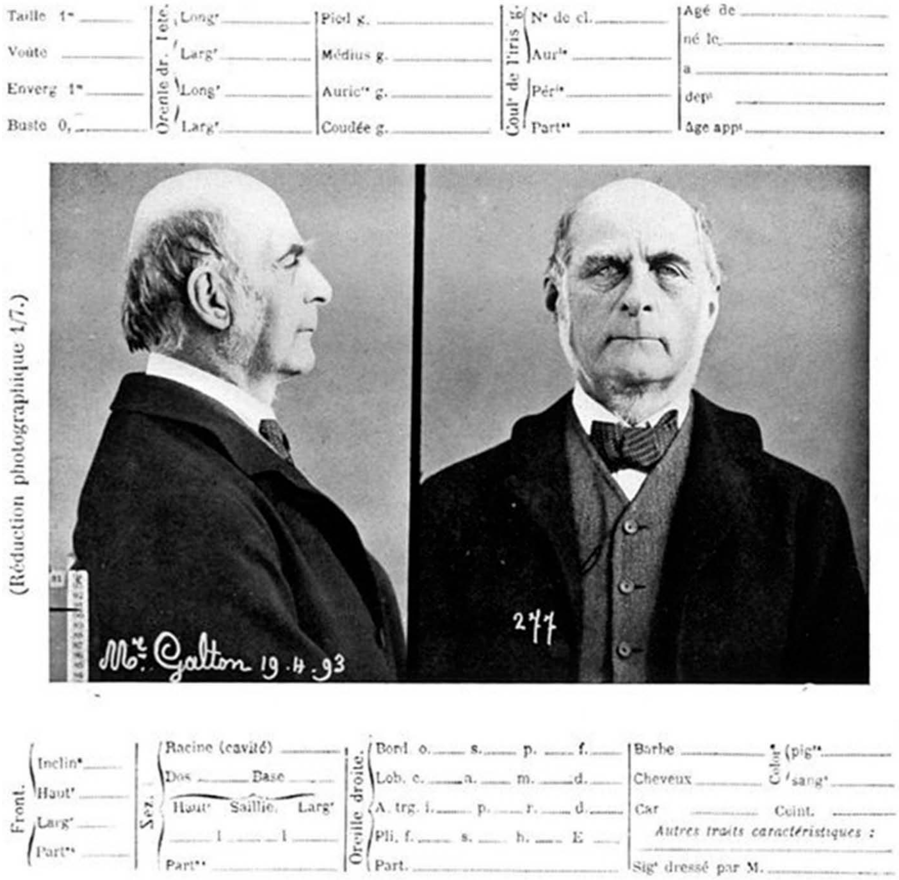


Figure 2.8 Dr. Henry Faulds. (Reprinted with permission from Asbaugh, D. 1999. *Quantitative-Qualitative Friction Ridge Analysis*. Taylor & Francis: p. 25.)

2.4 Criminal Records and Classification Systems

Alphonse Bertillon, a French scientist, is credited with devising the first anthropometric method of criminal identification and classification.[3] Anthropometry is the measurement of biological characteristics. Classification is a method of organizing criminal records so they may be relocated in order to compare them with new arrests. Criminals were initially identified through extensive, if primitive, photographic records. The records were called rogues' galleries. A recidivist could give a police officer a fake name, but a photograph, now known as a "mug shot," could identify the criminal's true identity. However, it is fairly simple to change one's appearance with a simple haircut or adjustment in facial hair or clothing.

Bertillon's method of classification was based on anthropometry or anatomical measurements. This method is also known as Bertillonage. The justification for this method of identification is based on the randomness of physiological variation. Bertillon devised a system of classification for arrestees based on physiological measurements recorded on a card bordering a mug shot (Figure 2.9).



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Mr. Galton 19.4.93

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Front. Inclin'
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Nez. Racine (cavité)
Dos Base
Haut' Saillie Larg'
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Oreille droite. Bord o. s. p. f.
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A. trg. i. p. r. d.
Pli. f. s. h. E
Part.

Barbe
Cheveux
Car
Color' (pig''
sang'
Ceint.
Autres traits caractéristiques :
Sig' dressé par M.

Figure 2.9 Sir Francis Galton's Bertillonage card was recorded when Galton paid a visit to Alphonse Bertillon's laboratory in 1893.

While Bertillon's assumptions were theoretically sound, based on the concept of natural variation, there were several problems with this form of classification. One hindrance was the need for specialized equipment and measuring tools. Many of these items were cumbersome. The process was also time-consuming, requiring very specific measurements. Another flaw of Bertillonage is that it does not take into consideration the proportions between height and limb length. Also, arrestees did not always cooperate with their captors. They would not remain still long enough for an accurate battery of measurements to be taken and recorded (Figure 2.10).

At that time, there was much debate about whether a Bertillonage card or fingerprint card should be the preferred criminal record format. There was a story circulated in newspapers about two men who were arrested and booked at Leavenworth Penitentiary.[13] One of these men was William West, and the other was named Will West. William West was arrested in 1901. Will West was arrested in 1903. When Will West's anthropometric measurements were taken, the records clerk searched the files and matched his anatomical dimensions with William West's previous Bertillonage record. When confronted with this, Will West asserted that he had never been arrested before and that the record the clerk found did not belong to him.

They were, in fact, two different men, similar in appearance with similar anthropometric measurements (Figure 2.11). In this case, fingerprints easily distinguished these two men (Figure 2.12). This event, whether or not it is based in fact, occurred right around the time Leavenworth Penitentiary abandoned Bertillonage and began to routinely fingerprint all incoming inmates. Since fingerprints were considered a superior form of identification, Bertillonage was replaced not only in the United States but also throughout the world.

The population explosion of the industrial revolution led to a dramatic increase in criminal activity. By the late 1800s, it became clear that a classification system was needed to organize the large volume of fingerprint records so they might be easily filed and searched. Two men are credited with devising the two most enduring systems of fingerprint classification: Juan Vucetich and Sir Edward Henry.

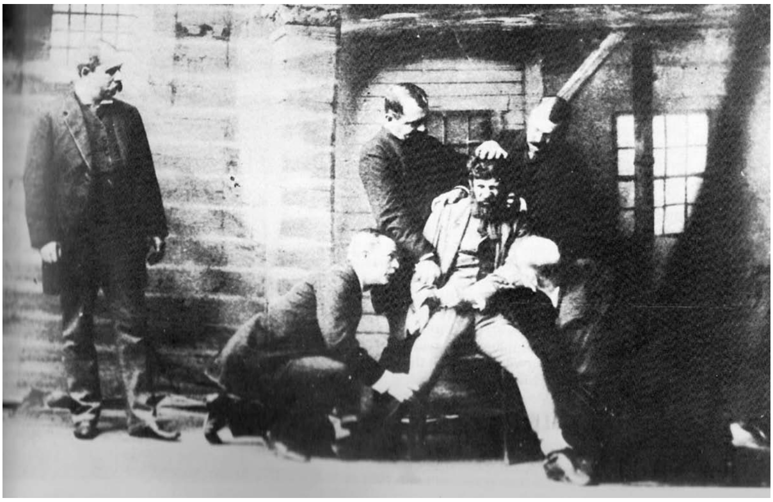


Figure 2.10 An uncooperative suspect is restrained for the purpose of taking anthropometric measurements.

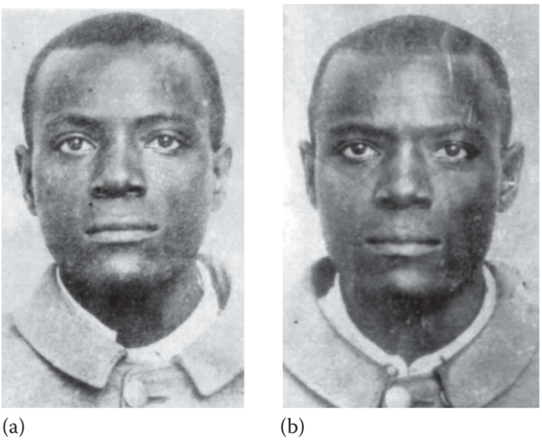

(a) (b)

Figure 2.11 Will West and William West.

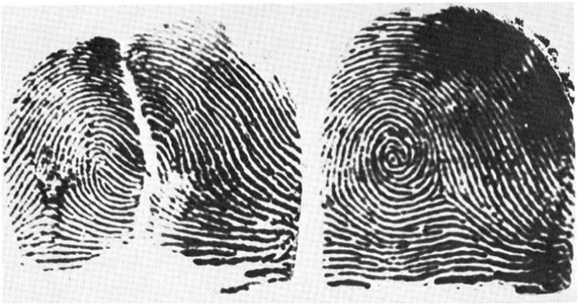


Figure 2.12 The fingerprints of Will West and William West.

Juan Vucetich was a Croatian immigrant to Argentina who became a statistician at the Buenos Aires Police Department (Figure 2.13).[2] Vucetich rose to become the head of the Identification Bureau.[2] In 1891, he read Galton's research and realized the superiority of fingerprints to Bertillonage.[2] Vucetich developed the first classification system still in use today in mostly Spanish-speaking countries. This system, which he called dactyloscopy, resulted in his 1904 publication, *Dactiloscopia Comparada*.[14] Vucetich classified fingerprint cards by assigning letters and numbers to pattern types found on each finger, starting with the thumb. The alphanumerical designation of the right hand is located in the numerator; the alphanumerical designation of the left hand is located in the denominator. Thus, the first system of classification was devised.[3]

Juan Vucetich was instrumental in solving one of the first murders to be solved by fingerprint evidence at a crime scene occurred in Buenos Aires in 1892. Two children were found murdered in Buenos Aires in 1892.[2] The children's mother, Francisca Rojas, accused a man named Velasquez of the crime. She claimed he was a jilted lover.[2] Rojas was in love with another man. When Inspector Alvarez, an investigator who was trained by Vucetich, examined the crime scene, he found a bloody thumbprint on the door.[2] After comparing and matching Rojas' fingerprints with the bloody fingerprint found on the door, he confronted her, and she confessed to killing her own children.[2] While the bloody thumbprint

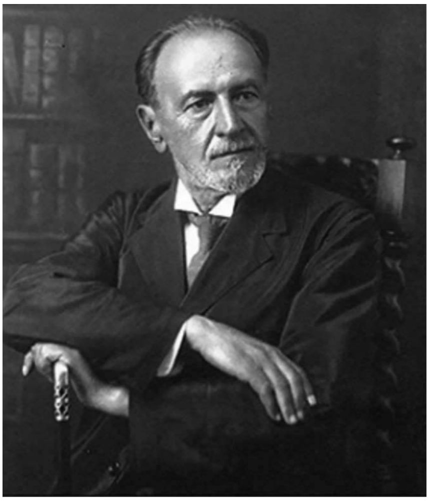


Figure 2.13 Juan Vucetich.

did not in itself prove Rojas committed murder, it did compel her confession. In 1894, Mark Twain introduced the use of fingerprints as evidence to popular culture in a novel entitled *Pudd'nhead Wilson*.[2] In the plot of this story, the principal forensic evidence from a homicide is a bloody fingerprint.

Several British fingerprint pioneers worked on classification systems around this time, including Sir Edward Henry, Sir Francis Galton, and Sir William Herschel. Sir Edward Henry, the inspector general of police in Bengal, India, is credited with developing the classification system used throughout the English-speaking world for the next 100 years. The classification system was the result of a collaboration between Henry, an Indian police officer and mathematician named Khan Bahadur Azizul Haque, an Indian police officer named Rai Bahadur Hem Chandra Bose, and Sir Francis Galton.[15] Similar to the Vucetich system, the pattern types are given specific designations and the formula is represented in fraction form. The even-numbered finger designations are located in the numerator, and the odd-numbered finger designations are located in the denominator. Unlike the Vucetich classification system, the fingers are assigned numbers, starting with the right thumb. The various classification systems will be explained in more depth in Chapter 4.

The beginning of the twentieth century marked the beginning of fingerprints as the primary means of identifying criminals throughout the world. The classification systems devised by Henry and his colleagues, as well as Juan Vucetich, allowed a substantial volume of fingerprint cards to be efficiently organized, filed, and retrieved. The first fingerprint bureau to house, classify, and analyze these fingerprint records was established at Scotland Yard in London, England, in 1901 (Figure 2.14).

2.5 The Twentieth Century

Fingerprinting was introduced to North America in 1903 when the New York State Prison System began routinely fingerprinting inmates.[2] In 1904, a team from Scotland Yard presented a display about criminal fingerprinting at the World's Fair in St. Louis,

THE VICTORIAN SOCIETY

Figure 2.14 A photograph of Scotland Yard (ca. 1800s).

Missouri (Figure 2.15).[2] They shared their knowledge with police officers from across the United States and Canada.[2] Throughout the 1900s, the science of fingerprint identification was described and refined, and new methodologies were developed. The first professional fingerprint organization was formed in Oakland, California, in 1915 and was named the International Association for Criminal Identification.[15] This is the oldest active international forensic association, since renamed the International Association for

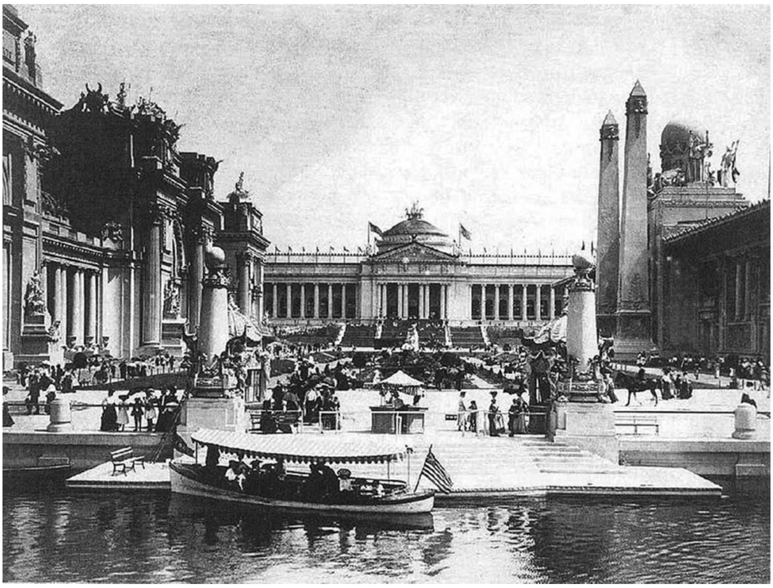


Figure 2.15 A photograph of the St. Louis World's Fair (ca. 1904).

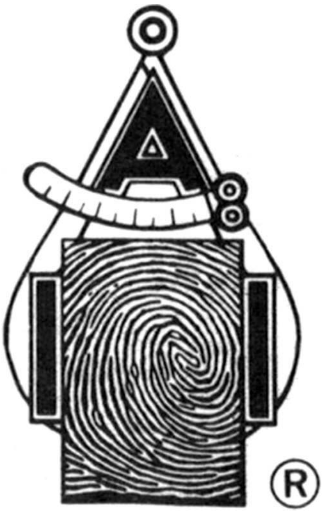


Figure 2.16 The logo of the International Association for Identification. (Reprinted with permission from the International Association for Identification.)

Identification (IAI) (Figure 2.16). In 1924, J. Edgar Hoover established the Federal Bureau of Investigation (FBI)'s Identification Division, followed by the FBI Laboratory in 1932.[2]

By the mid-1900s, the volume of criminal arrest records began to overwhelm the classification methods used to organize and store them. The consistency of population growth—and subsequent increase in crime and arrest rates—necessitated a new method of storing, sorting, and searching criminal fingerprint records. Throughout the 1960s and 1970s, the newly invented computer was considered a likely apparatus for digitizing and searching large volumes of data such as fingerprint records.[16] This goal was realized in the early 1980s when the Automated Fingerprint Identification System (AFIS) known colloquially as the "fingerprint computer" was developed, utilized, and disseminated in Europe, Asia, and North America.[3,16] AFIS computers are now ubiquitous law enforcement tools utilized worldwide. Technological improvements have resulted in faster, more accurate computers that have revolutionized the criminal justice system.

2.6 Paradigm Shifts

A paradigm shift is a fundamental change in the practice of and approach to a scientific endeavor. It is usually the result of a specific event that transforms a given scientific field. There have been several paradigm shifts in the field of fingerprint analysis that have changed the culture, practice, and research priorities of the field. This section discusses four such industry-altering circumstances that have occurred in the United States in the past 50 years.

The IAI resolution of 1973 sparked one such cultural shift.[17] Prior to 1973, many law enforcement agencies imposed a point standard: a minimum number of "matching" minutiae required to reach an identification conclusion when comparing an evidentiary print with a record print. That point standard was most commonly around 10–12 points. It was determined, after several years of research, that there was no conclusive scientific research to support a minimum point standard. The IAI resolution states, "no valid basis exists at this time for requiring that a pre-determined minimum number of friction ridge characteristics must be present in two impressions in order to establish positive identification."[17] No scientific studies had established a minimum number of points that would be required to be confident about an identification conclusion. Identifications cannot be determined based on only one variable: the number of minutiae in the print. Instead, multiple variables including both qualitative and quantitative factors are taken into consideration when evaluating two friction ridge impressions.

The invention of the silicone microchip led to the next paradigm shift in the early 1980s: AFIS. The AFIS computer allowed fingerprint analysts to record, store, and search fingerprints, negating the need to classify, file, and search tenprint cards by hand. The search algorithms of these computer systems allowed law enforcement to identify suspects in cases of stranger crimes. It led to a drastic decrease in some crime types.[16] These systems continue to evolve and serve as an invaluable tool for law enforcement today.

Another paradigm shift in the field of fingerprint analysis was generated as a result of a court case, Daubert v Merrell Dow Pharmaceuticals (see Section 18.9).[9] As a result of a judicial decision in this case, the following guidelines were recommended to determine the admissibility of scientific expert testimony:

- The science must be generally accepted in the relevant scientific community.
- The science must demonstrate a calculable error rate.
- The science must be testable.
- The science must be subject to peer review and publication.
- The science must have existing controls and standards.

These criteria are discussed in detail in Chapter 18. The establishment of these criteria led to more rigorous expectations for expert witnesses, whereas prior to this court case forensic experts were allowed to testify with insufficient critical inquiry.

A fourth paradigm shift was initiated with the publication of a document from the National Academy of Sciences (NAS) National Research Council, entitled "Strengthening Forensic Science in the United States: A Path Forward."[18] This report is often referred to as the "NAS report." This report recommends several avenues for shoring up the science behind fingerprint analysis and several other comparison sciences. The following are a selected list of recommendations in the NAS report for improving the fingerprint sciences:

- Certification for fingerprint examiners
- Regular proficiency testing
- Professional development and training
- Education—scientific undergraduate and higher degrees
- Research into multiple scientific areas that pertain to fingerprint analysis including error rates and statistics
- Blind verification of all fingerprint conclusions

All of these paradigm shifts and other cultural and scientific advancements have resulted in extensive improvements to the science of fingerprint analysis. There is currently a focus on improving transparency in the fingerprint analysis process; developing universal process standards; calculating error rates and statistical models; increasing awareness of human factors affecting fingerprint comparisons such as cognitive bias, workload, human perception, and expertise; and standardizing the nomenclature we use throughout the discipline[19] (see Chapter 19 for details).

Scientific and technological advancements continue to shape the field of fingerprint analysis. Advancements in chemistry have provided countless chemical reagents for developing and visualizing latent, or invisible, fingerprints from crime scenes. Advancements in technology continue to make fingerprint computers smaller, faster, cheaper, and more accurate. Scientific progress is not accomplished in a vacuum. It is built on the shoulders of those who came before us and consequently improved our own understanding through their work and scientific ingenuity. We continue to learn from our history as we reach into the future.

2.7 I Had a Case: AFIS and Archaeology

Forensic archaeologist Kimberlee Sue Moran (founder of Forensic Outreach) describes her research in traditional archaeology matching fingerprints on clay sealings using AFIS technology:

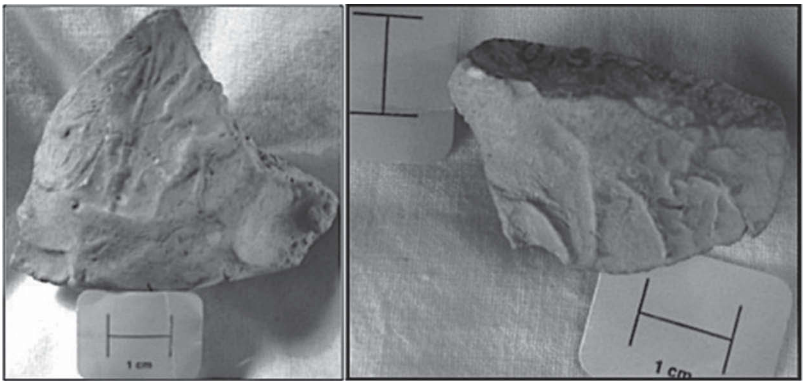
Cylinder seals and sealings are a ubiquitous feature of Mesopotamian archaeology. Seals are used on jar stoppers; bullae; mud brick; lumps of clay around string attached to bags, boxes, baskets; storeroom doors; and later on tablets and envelopes. As with other sealing practices in other ancient cultures, the act of sealing an object with clay and rolling one's personal cylinder seal across it was a means of verifying the activity or transaction and providing proof that tampering was absent. However, little is known about the individuals actually responsible for the act of sealing, record keeping, and other administrative duties. Sealing took place for hundreds of years before seals began to be inscribed with names or rank.

In the act of holding, molding, and sealing, the surfaces of the hand inevitably come into contact with the pliable clay leaving behind friction ridge detail. As the clay dries, the mark hardens and is preserved for millennia. Through the investigation of fingerprint remains some of the following questions may be addressed:

- Who has touched this object? When did they live?
- Can we deduce their employment, position, and/or status in society?
- Was a particular cylinder seal used by an individual or a group?
- Did an individual use one seal or multiple? Did it matter which seal was used for what?

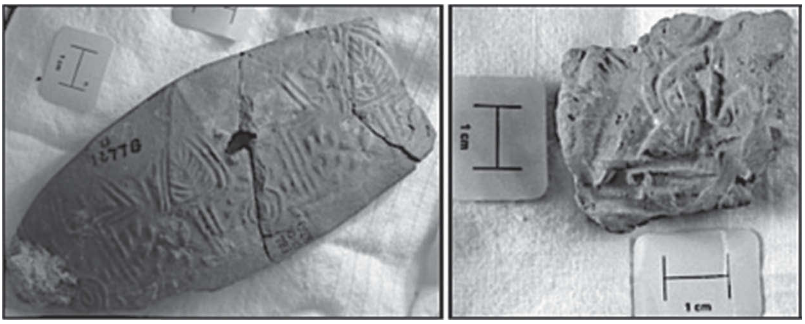
While the most desirable outcome is to "match" fingerprints found on multiple objects, both positive and negative results have ramifications, either confirming or negating archaeological theories on the use of sealing and on the individual active within the community and society at large.

A pilot study was conducted to determine whether it was possible to recover enough objects with friction ridge detail and whether the detail was sufficient for comparison. Four hundred forty sealings from the archaeological site of Ur (2600–2350 BC) were chosen for



(a) (b)

Figure 2.17 Clay sealings U13666 (left) and U13875 (right) from the archaeological site of Ur (2600–2350BCE). (Photo courtesy of Kimberlee Sue Moran, Director, The Center for Forensic Science Research and Education.)



(a) (b)

Figure 2.18 Clay sealings U14177 (left) and U12778 (right) from the archaeological site of Ur (2600–2350BCE). (Photo courtesy of Kimberlee Sue Moran, Director, The Center for Forensic Science Research and Education.)

this study. Roughly one-third of these sealings had some friction ridge detail present, and 90% of these had enough detail to make them worth photographing.

One hundred five digital images of friction ridge detail were entered into a local AFIS database. Two sets of potential matches were achieved. Two sealings—U13666 and U13875—were returned by the software as possible matches (Figure 2.17). U13666 appears to come from a door sealing. It is unclear what type of sealing U13875 is. The second set of positive results includes U14177, a sealing from what appears to be a jar with an impression containing animal designs, and a leaf-shaped seal containing a stylized design (U12778) (Figure 2.18). U12778 has multiple palmar impressions. The jar seal also seems to match another set of palmar detail, this time on a random lump of clay containing an incised star design. Having the same individual appear on three very different objects was surprising in light of our current theories of administrative functions within this society. Do archaeologists need to re-examine their views?

The case study described above was the first one of its kind to utilize computerized comparison techniques and to demonstrate that fingerprints are more than just a curiosity; they are artifacts in their own right, and as such, they can influence our interpretation of and inspire new questions about the object on which they are found. By using technology to match fingerprints between objects, new avenues of research and interpretation are created.

2.8 Chapter Summary

Knowing the history of fingerprint analysis gives us a better understanding of how the science evolved and where it is progressing in the future. Knowledge of the history of the science is also required for certification tests as well as courtroom testimony. Examples of ancient fingerprint patterns can be seen impressed into pottery and bricks. Fingerprints were used to represent personal identity in ancient China and India. Important modern European and American historical figures were Sir William Herschel, JCA Mayer, Dr. Henry Faulds, Sir Francis Galton, Alphonse Bertillon, Juan Vucetich, and Sir Edward Henry.

Anthropometry, or Bertillonage, was the first scientific form of criminal identification. Anthropometry was an identification system based on an arrestee's anatomical measurements. Fingerprints replaced anthropometry due to their superior individualizing power. Several classification methods were developed to categorize, store, and search for fingerprint records. The AFIS system largely replaced these manual classification methods. Paradigm shifts in the field of fingerprint analysis have hastened scientific advancements and improved scientific rigor throughout the discipline.

2.9 Review Questions

1. Why is it important to know the history of your science?
2. How did Sir William Herschel contribute to the field of fingerprint analysis?
3. Which historical figure first published the concept that fingerprints are unique and may be useful for solving crimes?
4. Who wrote the first book on fingerprints in 1892?
5. What is fingerprint classification?
6. Why was Bertillonage an inferior method of criminal identification to fingerprinting?
7. Who was responsible for developing the fingerprint classification system used primarily in English-speaking countries?
8. What contributions did Juan Vucetich make to the science of fingerprint analysis?
9. What is AFIS?
10. What significant paradigm shifts in the United States have changed the course of the fingerprint analysis field?

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Embryology and Physiology

3

> One who undertakes an intensive study of dermatoglyphics finds himself led into fascinating excursions throughout the realm of… the natural history of man.
>
> **Harold Cummins**[1]

LEARNING OBJECTIVES

- Describe persistence and uniqueness in the context of embryological and physiological development.
- Describe cell differentiation.
- List the epigenetic factors influencing fingerprint development.
- Explain how friction ridges and minutiae are formed in utero.

3.1 Biological Uniqueness

Fingerprints have historically been touted as unequivocally unique. Recently, the broader scientific community has challenged this claim. How can fingerprint examiners make this bold assertion? As there is no way to compare every fingerprint in the world with every other fingerprint in the world, we can never prove absolute uniqueness. However, the historically established science behind fingerprint examinations, coupled with intrinsic variation in nature, contribute to the ability to express the conclusions of fingerprint examinations with confidence and scientific reliability.

You may have heard the adage "nature never repeats itself." Natural variation is the notion that no two things in nature are exactly alike. No two ears of corn have been found to have the same pattern of kernels. No two zebras have been observed with the same pattern of stripes. No two cheetahs have been shown to have the same pattern of spots; and no two fingerprints have been discovered with identical configurations of minutiae.

Minute differences between similar biological entities are due to the complex biochemical processes that create every cell of every organism. Natural variation is especially apparent when organisms are viewed on a microscopic scale. Two objects that look alike to the naked eye may appear very different under a microscope. Cummins and Midlo state, "Corresponding parts of the same species may seem to present little or no difference if the inspection is merely casual. But many unlikenesses become apparent if the objects are examined closely, and the number of differences increases as attention is directed to more and more minute characteristics."[1] In a letter to the editor of the *Journal of Forensic Science*, John Thornton wrote about this assumption of uniqueness as "The Snowflake Paradigm," since it is commonly believed that no two snowflakes are the same.[2] He further describes this uniqueness premise as it relates to fingerprint analysis:

> The assumption of absolute uniqueness on the part of all tangible objects is a doctrine that has pervaded the interpretation of physical evidence. The doctrine generally takes one of two forms. The first is the metaphysical argument advanced by a number of classical philosophers (Heraclitus, Parmenides, Zeno and Plato), and further developed in the 17th century by Leibniz. This argument states that an object can be identical only to itself.
>
> The second form of the uniqueness argument is the one invoked for forensic science purposes. It too is generally accepted as true, but since it has an empirical component it is probably not susceptible of direct testing. This form of argument is frequently voiced as "Nature never repeats itself," and is attributed to the Belgian statistician Quetelet. (As an aside, what Quetelet actually said was that "Nature exhibits an infinite variety of forms")....[2]

It is an oversimplification to state that no two snowflakes are alike. Such a statement is philosophical rather than scientifically accurate and verifiable. Since we could never compare every fingerprint to every other fingerprint in the world, just as we could never compare every snowflake, we must understand how they are formed to understand the concept of biological uniqueness.

In order to appreciate the inherent biological differences that make fingerprints distinct, we must first begin with a discussion about how fingerprints are generated. Human embryological development is a complex process that starts with the joining of two cells, the sperm and the egg. Embryology, or developmental biology, is the study of the development of an organism from the egg stage through birth. Three fundamental aspects of developmental biology are cell growth (how cells grow and divide), cell differentiation (what kind of cells they will become), and morphogenesis (what structures the cells will form).[3]

After the fertilization of the egg by the sperm, the process of cell growth through mitosis, or cell division, begins (Figure 3.1). Initially, all cells look alike. These cells are called stem cells. As development continues to the embryonic stage, cells begin to differentiate. They change from stem cells into specialized cells. The word differentiation means, "to become different." Differentiation occurs when a cell is given a biochemical signal that controls what type of cell it will become. A stem cell may differentiate into a liver cell, a red blood cell, or a kidney cell. Other stem cells might become epithelial cells, which can then differentiate further into many different types of skin cells.

Cell signaling molecules and complex biochemical processes are the result of gene expression. Even though every nucleated cell in your body contains your entire genome, or genetic code, only a small part of that genetic code is expressed, or used. Some genes are turned on; some genes are turned off. Many different processes control the turning

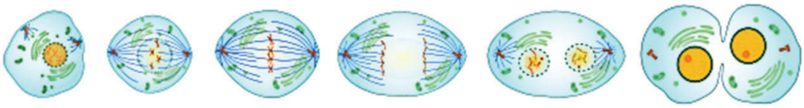

Figure 3.1 Mitosis is the process in which one cell replicates its DNA and splits into two cells.

on and off of genes regulating the development and differentiation of each cell in the human body.

The environment also plays a part in cell differentiation in ways that the field of epigenetics is elucidating. Epigenetics is the study of things that control gene expression outside the genetic code itself.[3] Epigenetic factors influencing friction ridge growth in utero may include the mother's nutrition, disease, environmental factors, or the position and surrounding environment for the fetus.

There are 20,000–30,000 genes in the human genome and a multitude of factors controlling how each of these genes is expressed in the human body.[4] There are simply too many factors controlling the various aspects of biological development for any two organisms to develop in the exact same way. This is the basis of biological uniqueness and the foundation for understanding the physiology of friction ridge skin.

3.2 Layers of the Skin

An understanding of the uniqueness of fingerprints necessitates an understanding of the physiology of human skin and the developmental processes that create it. Human skin is not one homogenous layer of tissue. It is a complex of many layers, each with distinct functions and morphologies. The skin is the largest organ of the human body, with important functions including homeostasis (regulation of body temperature), water retention, the synthesis of vitamin D, protection from the elements, and sensation (the sense of touch).[5] Skin also has an excretory function.[5] Water and waste products from inside the body are collected by the sweat glands and excreted through the sweat pores on the surface of the skin (Figure 3.2).[6]

The skin is made up of three main layers: the epidermis, the dermis, and a layer of subcutaneous fatty tissue known as the hypodermis.[5] The epidermis is the top section of skin stratified into five layers: the stratum corneum, the stratum lucidum, the stratum

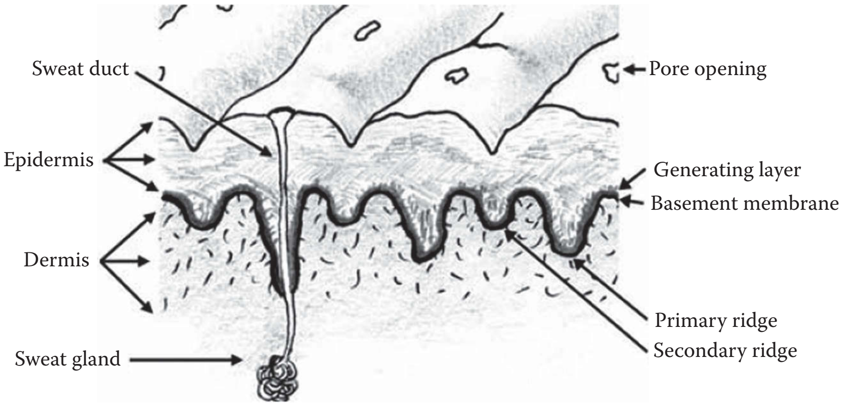

Figure 3.2 A cross section of friction ridge skin.[15] (Reprinted with permission from Wertheim, K. and Maceo, A. The critical stage of friction ridge pattern formation, *J. Forensic Identif.* 2002, 52(1), p. 37.)

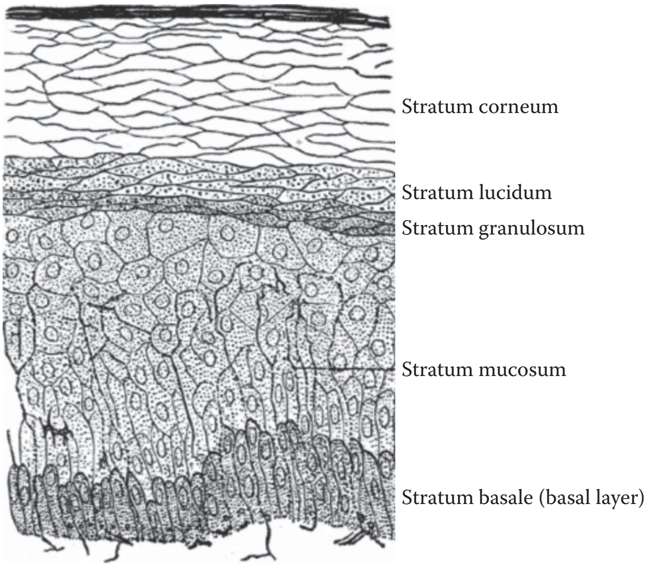

Figure 3.3 The five layers of the epidermis—stratum corneum, stratum lucidium, stratum granulosum, stratum mucosum, and stratum basale.[16] (From Lewis, *Gray's Anatomy, 20th Edition*, 1918.)

granulosum, the stratum spinosum, and the stratum basale (Figure 3.3).[5,7] The stratum corneum, otherwise known as the "horny layer," is the top layer of the skin. This is the layer we can see. This durable outer "shell" is composed of keratinocytes, a type of skin cell filled with fibrous protein bundles called keratin.[5,8] Most of the cells of the epidermis are keratinocytes.[5]

The deepest layer of the epidermis, the stratum basale, is also known as the basal layer. The basal layer is a single layer of epithelial cells responsible for generating the cells that are destined to become friction ridges. The basal layer is constantly generating new cells that migrate through the layers of the epidermis to the surface of the finger. Cells are generated through the process of mitosis, the splitting of one cell into two individual cells. As basal cells divide, they push up through several layers of skin (Figure 3.4).[5,9] Throughout this process, adjacent cells are bound to each other via adhesion proteins known as desmosomes.[1,5,8] When the skin cell reaches the surface, it is shed and replaced by the cell beneath it. This process of cellular generation, migration, and shedding is a continuous cycle.

Below the epidermis is a deeper layer of skin tissue known as the dermis. The basement membrane zone (also called the dermal–epidermal junction) attaches the dermis to the epidermis.[5,8,10] This zone is composed of fibers from the basal cells reaching into the dermis, as well as fibers from the dermis reaching toward the basal layer.[5] Just like the roots of plants, the fibers anchor the layers together. The dermis is a thick, elastic layer that contains the sweat glands, blood vessels, and nerve endings.

Dermal papillae—structures found in the upper layer of the dermis—are peg-like projections pushing up toward the epidermis.[5,11–13] The dermal papillae create a greater surface area for the transfer of nutrients from capillaries to both the dermis and epidermis. All of these structures develop while the fetus is developing in utero.

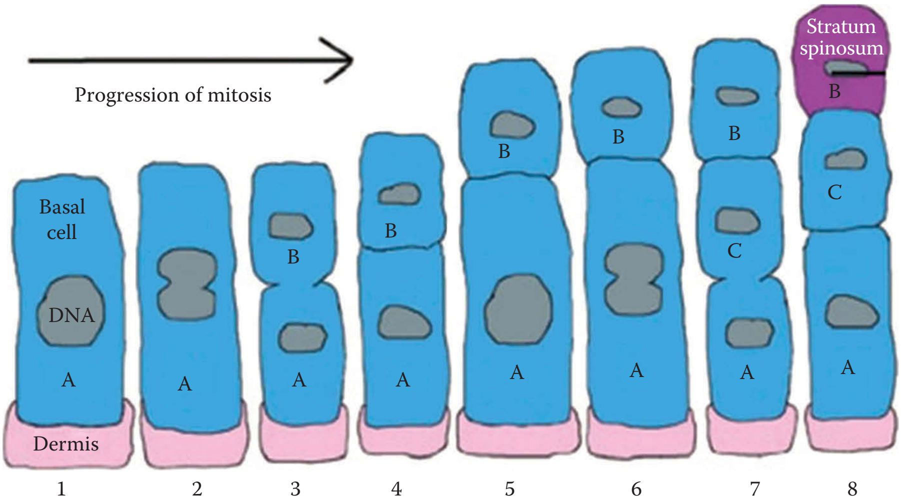

Figure 3.4 Basal cells (A) undergo mitosis. The resultant daughter cells (B and C) are pushed up through the layers of the skin.[17] (Reprinted from Maceo, Alice, "Anatomy and Physiology of Adult Friction Ridge Skin" In *The Fingerprint Sourcebook*, Washington, DC: National Institute of Justice, 2011, p. 2–7.)

3.3 Embryological Development of Friction Ridges

Friction ridge skin forms within the first two trimesters of human fetal development. The sequence of the developmental stages is fixed, but the duration of each stage varies by individual (Table 3.1). These processes may even overlap, creating even more natural variation. Fetuses grow and develop at different rates, just as teenagers going through the developmental process of puberty will grow and develop at different rates. However, each individual cell, structure, and organism experiences differential growth. Differential growth is "a difference in the size or rate of growth of dissimilar organisms, tissues or structures."[14]

Table 3.1 **Embryological Development of Friction Ridges Over Time**

Weeks	Developmental Processes
6–7	Webbing between cartilaginous "fingers" begins to dissipate Volar pads appear
7–10	Volar pads grow Volar pads vary in position, size, and shape
10–15	Volar pads regression begins Epidermal ridge cells begin to replicate in basal layer Primary ridges form Sweat glands form
15–17	Secondary ridge formation initiates The top layer of the epidermis (stratum corneum) forms
17–25	Secondary ridges form between all primary ridges Ridges are apparent on skin surface Dermal papillae form Friction ridges have adult morphology

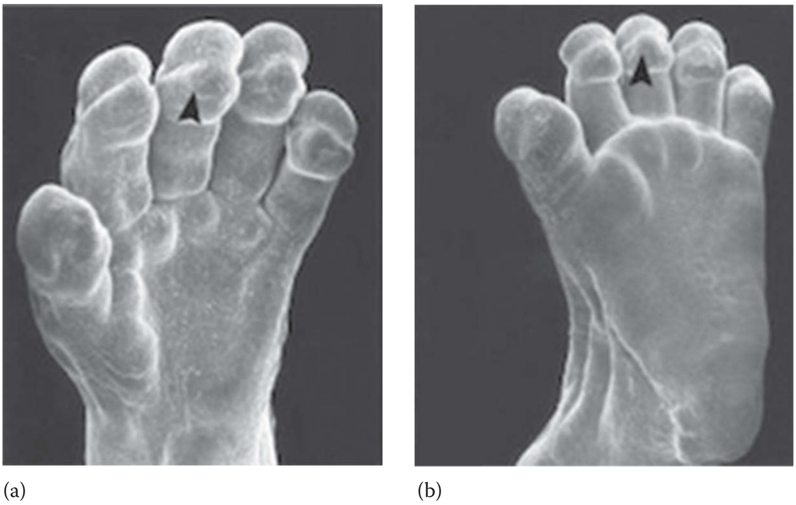
(a) (b)

Figure 3.5 Scanning electron micrographs of the human embryonic hand (a) and foot (b) at the end of the second month of development. The volar pads are indicated with black arrows.[18] (Reprinted with permission from Carlson, Bruce M., *Human Embryology and Developmental Biology*, Oxford: Elsevier, 2014, (Figure 9.4).)

Cell differentiation leads to differential growth, which results in morphogenesis. The word morphogenesis comes from the Latin words morpho, meaning shape, and genesis, to come into being. In this case, morphogenesis refers to the origin of biological shape or form. This process starts with the development of the fetal hand around 6 weeks after the egg is fertilized.[1,11] Between 6 and 7 weeks gestation, the paddle-like hand of the fetus begins to resemble a hand with fingers.[1,11] The webbing initially observed between the "fingers" begins to dissipate.[11]

Around this time, swellings called volar pads grow on the fingertips and palmar areas of the developing hand (Figure 3.5).[11–13,15,16] In most mammals, such as dogs and cats, volar pads are present throughout adulthood. You can observe these volar pads in many nonprimate mammals. They are the soft swellings on the bottoms of an animal's paws (Figure 3.6). Since nonprimate mammals do not use hands to grasp and manipulate objects, friction ridges do not form to replace volar pads. The volar pads serve as padding for walking on all fours.

Volar pads continue to grow between 6 and 10 weeks of human fetal development.[1,11–13,16,17] They then start to vary in position, size, and shape. Around the tenth or eleventh week, the volar pads begin to recede or deflate (Figure 3.7).[11–13,18] This initiates the development of primary friction ridges in what Alfred Hale of Tulane University calls "localized increases in basal cell activity."[19] During the process of volar pad recession, the epidermal layers begin to form and thicken. Around weeks 14 and 15, sweat glands form and coil up within the deeper layers of the dermis, the thicker layer of tissue below the epidermis.[11,12] The sweat glands are connected to the surface of the epidermis where they will expel sweat through pores spaced along the friction ridges.

The cells that will form the primary friction ridges, those that we can easily see on our fingers and palms, differentiate in the deepest layer of the epidermis, the basal layer.[11–13,19]

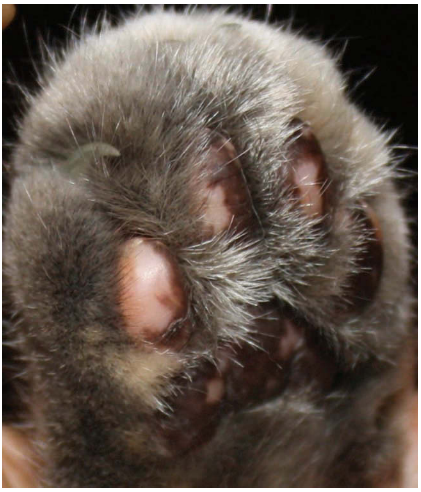

Figure 3.6 Volar pads on an adult cat.

This is where the initial formation of friction ridges takes place. Dr. William Babler, a well-known researcher in the field of prenatal friction ridge development, refers to these developing epidermal ridge cell areas as “localized cell proliferations” that start in the center of the regressing volar pad.[12] Ridges start to form in different areas of the receding volar pad and spread out to eventually join and form the patterns and minute details we see on our fingers.

Friction ridge formation is effected by the growth stresses of the changing skin surface. As volar pads recede, and the skin stretches and compresses. Friction ridges develop at right angles to the plane of growth stresses and compression forces in the receding volar pad.[10–12,19] Primary ridges will continue to form and push up through the epidermal layers to the surface until around week 17 of prenatal development.[11,15]

Between weeks 15 and 17, secondary ridges begin to form.[10–12,15,17] Secondary ridges are minute ridges that form in the furrows, or valleys, between primary friction ridges. They are found between every primary ridge deep in the epidermis, but contain no sweat

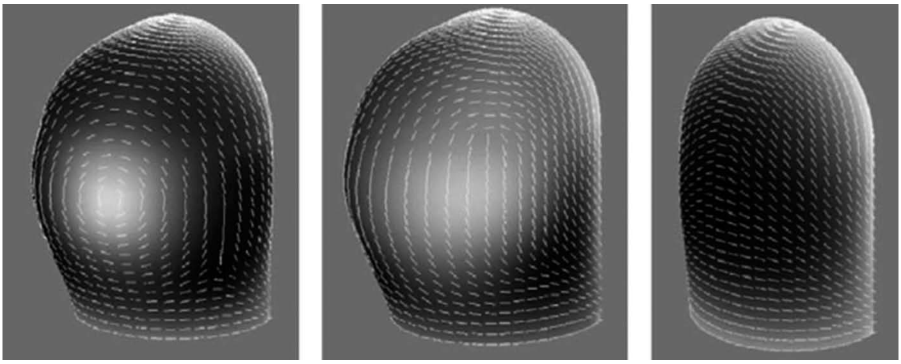

Figure 3.7 Volar pad recession.[19] (Reprinted with permission from Kucken and Newell, Fingerprint formation, *J. Theor. Bio.* 235(1), p. 79.)

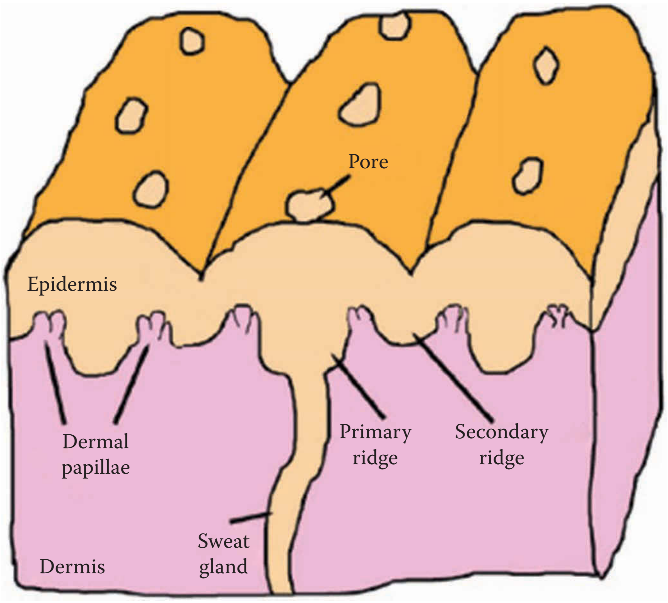

Figure 3.8 Schematic cross section of friction ridge skin showing the primary and secondary ridges and dermal papillae.[17] (Reprinted from Maceo, Alice, "Anatomy and Physiology of Adult Friction Ridge Skin" In *The Fingerprint Sourcebook*, Washington, DC: National Institute of Justice, 2011, p. 2–5.)

glands (Figure 3.8).[9] Secondary ridge formation signals the end of primary ridge formation. Friction ridges do not develop only on the fingers, but also spread out across the surface of the palm, finger joints, feet, and toes.

Dermal papillae also form around this stage of development between the primary and secondary ridge structures.[11,19] Hale writes, "The dermal papillae are shaped through pressures and growth stresses exerted by an epidermis which is increasing in area as well as thickness."[19] At around 19 or 20 weeks, primary ridge development is completed and friction ridges can be seen on the surface of the skin.[11,12] By week 25, friction ridge formation is complete.[11–15,19] At this stage, the newly developed friction ridges are fully formed and will persist throughout an individual's lifetime.

3.4 Embryological Development of Minutiae

Ridge units are the building blocks of friction ridges. Each ridge unit is composed of one sweat gland and a corresponding sweat pore. Friction ridges are composed of hundreds of friction ridge units each fused to its neighbor to form a generally continuous structure. There are many factors that influence the development of each friction ridge unit. The fusion of various friction ridge units results in a diversity of primary ridge structures and morphology. The width and height of each ridge unit are variable, resulting in friction ridges that are not smooth but contoured, similar to mountain ranges. There is variation in the widths of ridge units, the depth of ridge penetration into the dermis, the alignment of the units, and the spacing between the ridges.[11,12] The placement, shape, and size of the

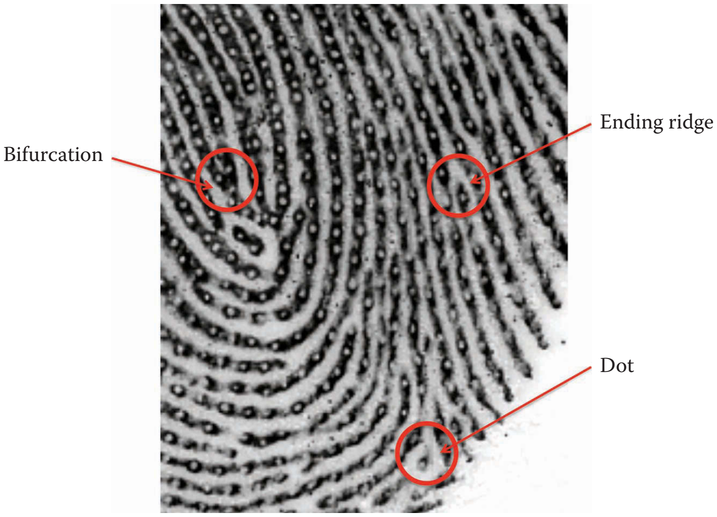

Figure 3.9 An enlargement of a fingerprint with visible minutiae: ending ridges, bifurcations, and dots.

pore on each ridge unit are also distinct. The three-dimensional morphology of each friction ridge unit results in distinctive structures.

Fingerprint patterns form as a result of volar pad morphology: low volar pads form arches, high volar pads form whorls, and volar pads that are off-center form loops. However, fingerprint patterns are not unique structures. The uniqueness within the pattern is found in the small details: the types and locations of minutiae. You will recall that there are three types of minutiae: bifurcations, ending ridges, and dots (Figure 3.9). Minutiae form as a result of the proliferation of primary ridges and growth forces as the surface of the skin changes in dimension and size during fetal development. Dr. William Babler states, "Minutiae reflect the formation of new ridges subsequent to the period of initial ridge formation."[12] As the hand grows, the increase in surface area allows the friction ridges to spread out, creating more room for new primary friction ridges to develop between their predecessors. Ridges continue to form in the open spaces until the process of primary ridge formation ends (Figure 3.10).[6]

As friction ridges develop, they do not always form a continuous curve. Growth stresses create ridge path deviations that result in bifurcations, similar to a fork in the road or a river flowing around a large boulder in its path. Alfred Hale examines the development of bifurcations in his 1951 publication, *The Morphogenesis of Volar Skin in the Human Fetus*.[19] Hale states that bifurcations "arise out of the lateral swellings described on the primary ridge" and further asserts that growth forces that are stretching the epidermis pull new ridge units away from the primary ridge, thus creating a forking or bifurcating ridge.[19] Thus, a bifurcation is a splitting apart of one primary ridge rather than the fusion of two separate primary ridges.

Ending ridges form as a result of the timing and rate of primary ridge proliferation. As the finger grows and spaces open up between primary ridges, new primary ridges form in the open space. They will continue to extend as friction ridge units fuse and lengthen the developing ridge. Eventually, around the fifteenth to seventeenth week of fetal development, the process of primary ridge proliferation stops. This terminates the extension process, and developing ridges come to an abrupt halt. This creates an ending ridge.

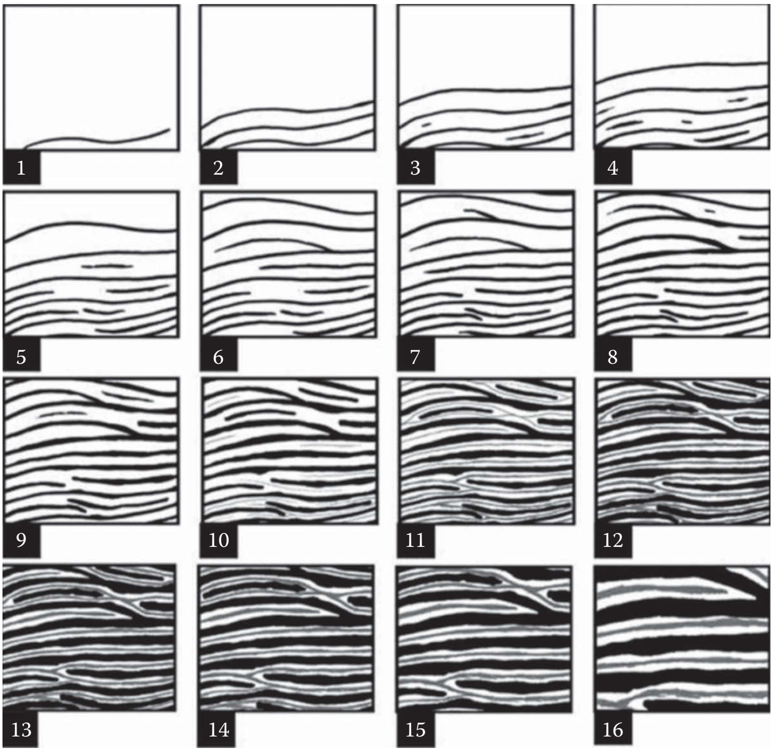

Figure 3.10 Line drawings representing the formation of minutiae as friction ridges develop in utero. The black lines represent friction ridges. The gray lines represent secondary ridges.[15] (Reprinted with permission from Wertheim, K. and Maceo, A. The critical stage of friction ridge pattern formation, *J. Forensic Identif.* 2002, 52(1), p. 51.)

If a new ridge began elongating just before primary ridge formation was terminated, it will not have had time to lengthen. This creates a short ridge. Short ridges can vary in length but may be as short as one friction ridge unit in length. These are frequently referred to as dots. Thus, ending ridges and short ridges are the result of the same process. When the proliferation of primary ridges stops, the ridge elongation stops.

Thus, as Hale states, “the minutiae are the products of the interaction between stress and the ability of ridges to multiply, as well as the chronology of their origin.”[19] Without random variability in friction ridge development and minutiae formation, fingerprints would not be distinctive. The natural variation found in friction ridges is the result of the properties and mechanisms of differential growth. The following are factors that contribute to the development of volar pads, ridge units, and minutiae and thus to the uniqueness of fingerprints[10–12,19]:

- Genetics
- Epigenetic factors (nutrition, position, environment, etc.)
- Growth stresses due to differential growth
- Volar pad topography (thickness, height, width, and contour)
- Compression due to volar pad recession
- Metacarpal bone formation and morphology
- Timing and rate of ridge maturation
- Vessel–nerve pairs in the dermal papillae

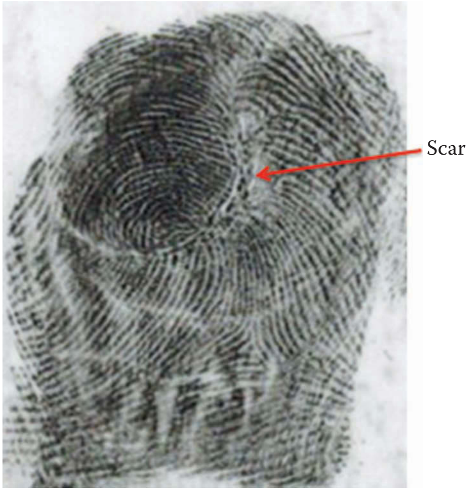

Figure 3.11 A photograph of an inked fingerprint with a visible scar through the core of the pattern.

3.5 Friction Ridge Persistence

The second premise that forms the basis for the science of fingerprint identification is the idea that fingerprints are persistent throughout one's life. If friction ridge formations were mutable, they would not be useful for identification. As was discussed earlier, the basal layer is the generating layer for the friction ridge patterns seen on the surface. The basal layer can be thought of as the blueprint for the building of friction ridges. The blueprint never changes. It is set for life. Every cell in the basal layer generates identical daughter cells through the process of mitosis throughout one's lifetime.

It is possible for changes to occur in isolated portions of the friction ridge pattern if the basal layer is cut, burned, or mutilated. When this occurs, a scar is formed (Figure 3.11). The dermis and the layers of the epidermis will be repaired, but the blueprint is damaged. Flattened keratinocytes will migrate upward, forming nonridged areas of skin within the friction ridge pattern.[5] These scars can be useful in the initial stages of the comparison process, since they may be distinctive in shape and size. Regardless of whether the structures of the epidermis are friction ridges or scars, they are persistent throughout an individual's life.

3.6 Abnormal Friction Ridges

In rare circumstances, friction ridges may appear abnormal due to a congenital skin disorder or as a result of medication. Genetic disorders include ridge aplasia, dysplasia, or hypoplasia. Ridge aplasia, otherwise known as epidermolysis or adermatoglyphia, is the complete absence of friction ridges on the epidermal surface.[5,20] In cases of ridge dysplasia, also referred to as ridge dissociation, friction ridges are segmented.[5] In many cases, a pattern type is not apparent. Hypoplasia occurs when friction ridges are shorter in height than those that form normally.[21] An analogy is that hypoplasia results in ridges that resemble hills rather than mountains.

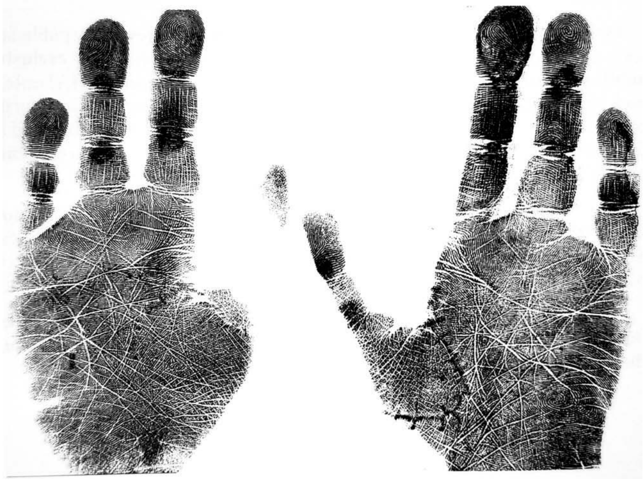

Figure 3.12 A photograph of a left and right hand displaying ectrodactyly, the congenital lack of fingers. (Reprinted with permission from Siegel, S. 2017. Back to basics: dactylography—questionable unusual interesting pattern. *J. Forensic Identif.* 68(1): p. 160. Image submitted by Kyle Fedewa, Biometrics and Identification Division, Michigan State Police.)

Chemotherapy drugs such as paclitaxel have been shown to alter the appearance of friction ridges.[22,23] This is known as hand-foot syndrome.[23] It causes the friction ridges to appear worn and negates the ability to take the individual's record prints. These malformations are the subject of continuing research.

Fingerprints may also appear abnormal due to natural processes such as aging or manual labor. As humans age, the skin becomes less elastic and an excess of creases may appear in the resulting friction ridge records. Friction ridges appear worn or indistinct. Similar characteristics are seen in the fingerprint records of individuals who perform manual labor on a regular basis. While fingerprint analysis is dependent on the premises of distinctions due to natural variation and persistence, even malformations in the friction ridge skin can be distinctive.

3.7 I Had a Case: Missing Digits

Occasionally, the development of the hand takes an abnormal turn. Congenital conditions such as syndactyly (webbed fingers) and polydactyly (extra fingers) are seen in a small percentage of the population. Figure 3.12 is an example of another congenital disorder: ectrodactyly (Figure 3.12).[24] Ectrodactyly is the absence of fingers. This example is from a case out of the United States. The individual has only eight fingers. While developmental abnormalities are rare, it is important to recognize them.

3.8 Chapter Summary

Friction ridge skin forms between the sixth and twenty-fifth week of fetal development. Three aspects of developmental biology—or embryology—that contribute to this process are cell growth, cell differentiation, and morphogenesis. Friction ridges are formed in the basal layer of the epidermis as the volar pads recede. As the cells are generated, they divide through a process called mitosis. The cells are then pushed up through the various epidermal layers to the surface, where they are shed and replaced by the cells beneath them.

There are many factors of friction ridge development that contribute to their uniqueness. These factors include genetic factors, epigenetic factors (nutrition, position of the fetus, environment, etc.), growth stresses, volar pad topography (thickness, height, width, and contour), compression due to volar pad regression, bone formation and morphology, the timing and rate of ridge maturation, and the presence of vessel–nerve pairs in the dermal papillae. Many of these processes also contribute to the formation and locations of minutiae. The basal layer of the epidermis forms the blueprint for the generation of friction ridges, which accounts for the persistence of friction ridge patterns. Congenital defects affecting the appearance of friction ridge patterns include ridge aplasia, dysplasia, or hypoplasia. Friction ridge malformation can also occur with manual labor, aging or cancer medications.

3.9 Review Questions

1. How do we know that no two fingerprints are alike?
2. What is cell differentiation?
3. What is epigenetics, and what does it have to do with fingerprint development?
4. Which layer of the skin is responsible for friction ridge generation?
5. How are friction ridge cells formed?
6. What are volar pads?
7. What factors contribute to the uniqueness of fingerprints?
8. How are bifurcations formed?
9. Which types of minutiae are formed due to the cessation of primary friction ridge formation?
10. What is a scar, and how does it form?

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Fingerprint Patterns and Classification

4

LEARNING OBJECTIVES

- Describe the characteristics of arches, loops, and whorls.
- Understand the purpose of fingerprint classification systems.
- Calculate the primary Henry classification from a tenprint card.
- Describe NCIC classification codes and their uses.

4.1 Fingerprint Patterns

As friction ridges spread out across the surface of the developing fingers, they form one of three patterns: an *arch*, a *loop*, or a *whorl* (Figure 4.1). Each pattern type can be broken down into several subpatterns, which will be discussed in detail later in this chapter. The pattern formed is dependent on the dimensions of the volar pad, its size, shape, and position on the finger.[1] Pattern type is a function of the volar pad's three-dimensional regression combined with the proliferation of friction ridges. As early as 1924, it was hypothesized that height and symmetry of the volar pad influence pattern formation.[2] "High," symmetrical volar pads form whorls, asymmetrical volar pads form loops, and "low" volar pads form arches.

While the minutiae within your fingerprint are distinctive, there is evidence to suggest that fingerprint patterns are inherited. The patterns we see on our fingerprints display what we will call *ridge flow*, which is an illustrative method of describing how the friction ridges form patterns.

Most fingerprint pattern types have one or more of the following features formed as a result of ridge flow: the *core* and *delta*. The core of a fingerprint, like the core of an apple, is the center of the pattern (Figure 4.2). It is the focal point around which the ridges flow. The second feature of most fingerprints is the delta (Figure 4.3). A delta is an area of friction ridge skin where ridge paths flowing in three different directions create a triangular pattern. These patterns appear similar to lake or river deltas: areas where the flow diverges.

4.2 Loops

The loop pattern is the most common fingerprint pattern found in the population. Approximately 60%–70% of fingerprints in the population are loops. Loops are patterns in which the ridges enter on one side of the finger, make a U-turn around a core, and exit out the same side of the finger. Figure 4.4 illustrates a variety of fingerprints with loop patterns (Figure 4.4). If you think of the loop as a physical structure, you can imagine that

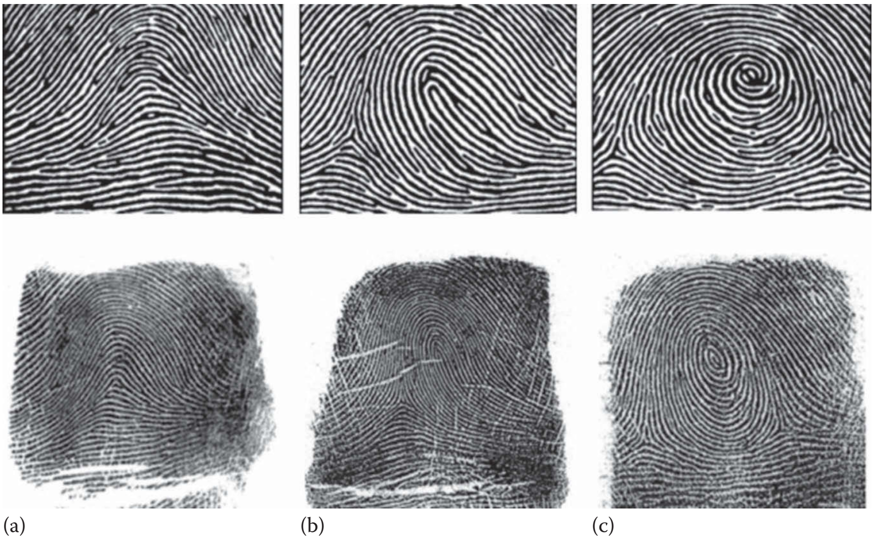


Figure 4.1 The three basic fingerprint pattern types: arches, loops, and whorls.

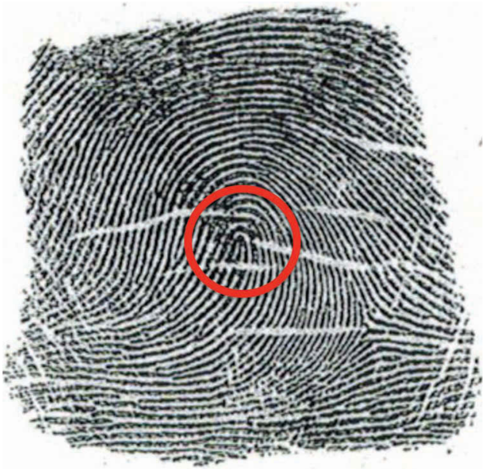


Figure 4.2 The core of a loop pattern.

water poured into the core will flow out only at one side of the print. A loop must also have at least one intervening, looping ridge between the delta and the core. This looping ridge is known as a *recurve*, which is another word to describe a ridge that makes a U-turn. The Federal Bureau of Investigation (FBI)'s "Fingerprint Training Manual" defines the loop pattern: "A loop is that type of pattern in which one or more ridges enter upon either side, recurve, touch or pass an imaginary line between delta and core and pass out or tend to pass out upon the same side the ridges entered."[3] Thus, the three requirements for a loop pattern are as follows (Figure 4.5):

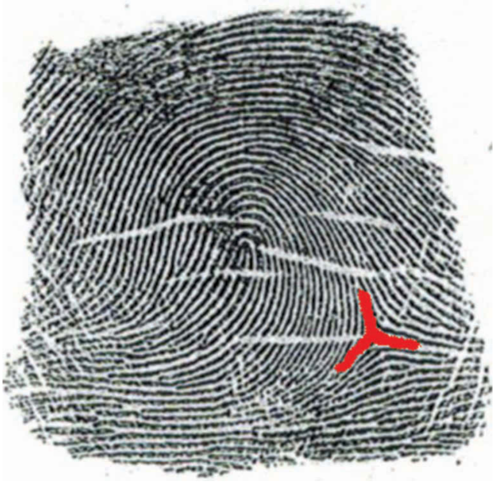


Figure 4.3 The delta of a loop pattern.

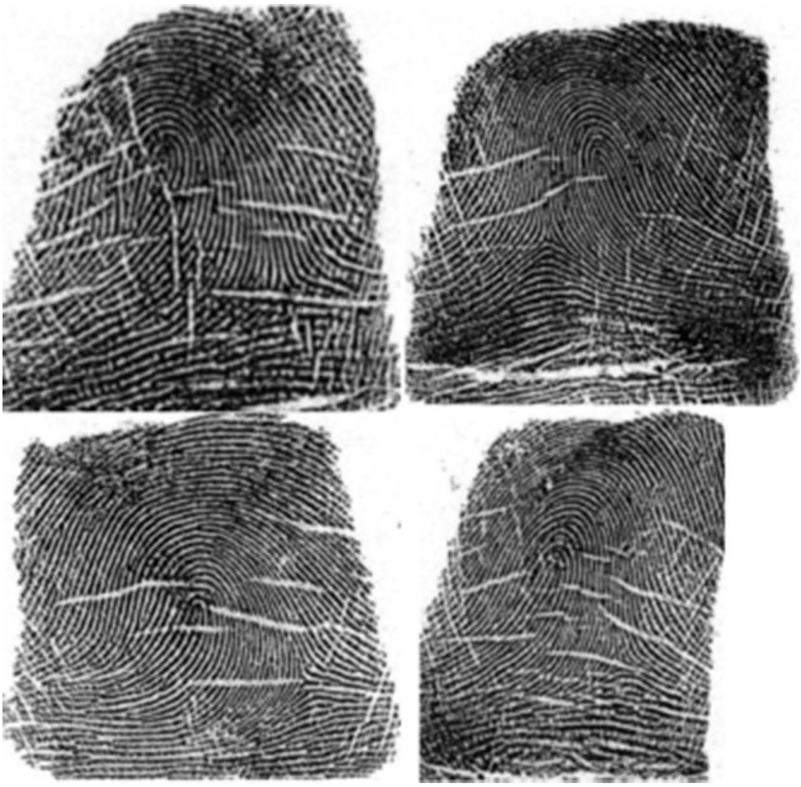


Figure 4.4 Various loop fingerprint patterns.

- A sufficient recurve
- One delta
- A ridge count across a recurving ridge (discussed in detail below)

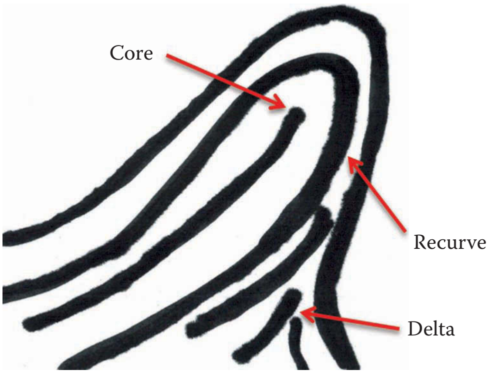


Figure 4.5 The three requirements of a loop pattern are a sufficient recurve, one delta, and a ridge count across a looping ridge.

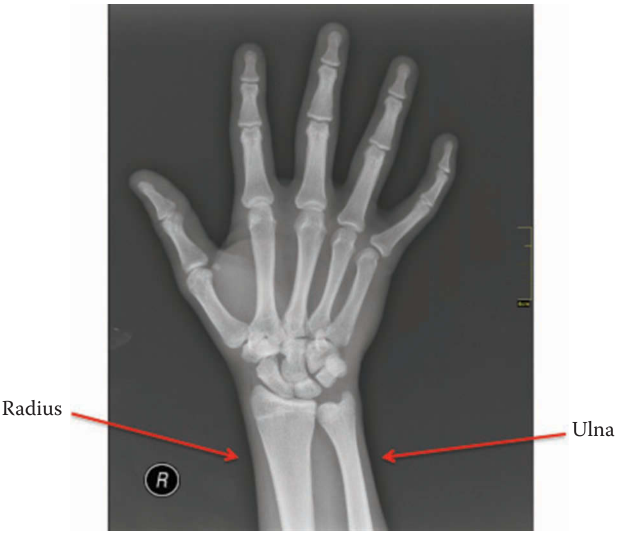


Figure 4.6 The bones of the forearm: radius and ulna.

There are two subcategories of loops: radial loops and ulnar loops. Radial and ulnar refer to the bones of the forearm, the radius, and ulna, as is shown in Figure 4.6. *Radial loops* are loops that are slanted toward the radius, the inner bone of the forearm. These loops flow toward the thumb. *Ulnar loops* are loops that are slanted toward the ulna, the outer bone of the forearm. The ulna is the bone associated with the elbow. These fingerprints flow toward the little finger of the hand.

When latent, or unknown, fingerprints are collected from crime scenes or from items of evidence, it is not possible to determine whether a finger on the right hand or the left hand made the loop pattern. In this case, we may refer to these loops as either right-slanted loops (also referred to as "right loops") or left-slanted loops (also referred to as "left loops").[4] It is interesting to note that most loops on the index, middle, ring, and little fingers are ulnar loops. If radial loops are encountered, they are most often found on index fingers of the hands.

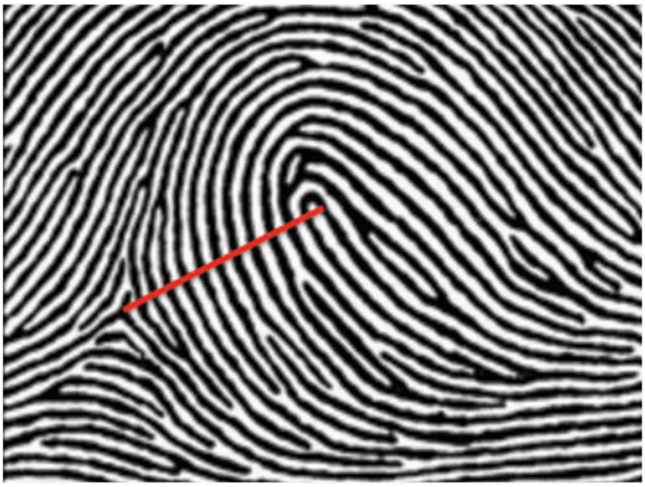


Figure 4.7 A loop pattern with a ridge count of 12.

Loops are further characterized by their *ridge count*. Ridge count refers to the number of friction ridges that cross an imaginary line between the core and delta (Figure 4.7). Ridge count, similar to pattern-type formation, is the result of volar pad morphology and the rate of embryological development. If friction ridges spread across the surface of the volar pad at a faster rate, the volar pad will have less time to recede, which allows for more ridges to cover a larger area of volar skin.[5] If the rate of friction ridge development is slower, the volar pad has more time to recede before the friction ridges proliferate, and the ridge count may be lower.[5]

The FBI's *Fingerprint Training Manual* describes how to "count" ridges.[3] The counting begins at the delta. But where do we start counting if the delta is not a defined point within the pattern? Deltas are not often well-defined triangles, but are instead ambiguous areas of ridge flow. The FBI manual defines a delta as "that point on a ridge at or nearest to the point of divergence of two typelines, and located at or directly in front of the point of divergence."[3] In order to find the point of origin at which to start counting, you must find the *typelines*.

Typelines are the two friction ridges, either continuous or broken, that diverge from the delta in opposite directions and surround the main pattern[3] (Figure 4.8). If the ridge forming the typeline is broken, the typeline continues with the neighboring ridge away from the core.[3] The midpoint of the delta is located where the two typelines divide or immediately in front of that point (nearest to the core).[3]

The ridge count proceeds from the delta to the core. The core of the print may be an obvious point at the center of the patterns, or it might be more ambiguous. If the innermost ridge is a loop, count to a point just past the center of the print. Once you have found the delta and the core, you can count the intervening ridges. This is the ridge count used to characterize a loop pattern.

4.3 Whorls

The second most populous fingerprint pattern type is the whorl, which is found in approximately 30%–35% of fingerprints in the population. A whorl is a circular pattern. Most of

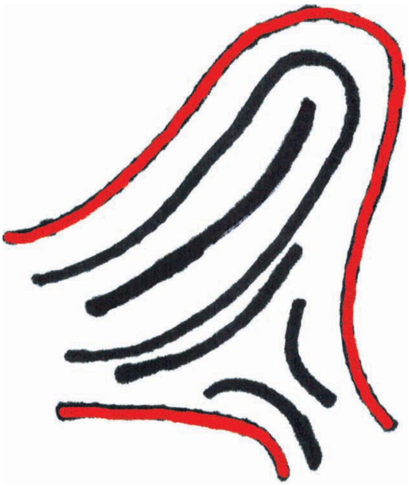


Figure 4.8 A line drawing of a loop pattern. The thicker lines demonstrate the typelines of this particular fingerprint.

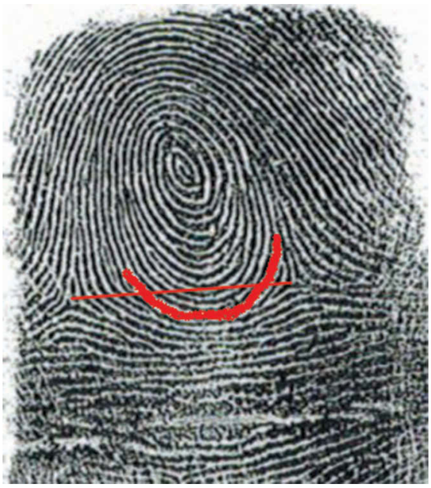


Figure 4.9 A plain whorl. A line from delta to delta cuts through several recurving ridges, as shown.

the friction ridges in these patterns make complete circuits around a central core. Whorl patterns must have at least two deltas and a sufficient recurve in front of each delta.[3] There are four subcategories of whorls: plain whorls, double-loop whorls, central pocket loop whorls, and accidentals.

Plain whorls are the most common type of whorl. Some plain whorls resemble targets. The core is well defined at the "bull's-eye" of the target. Some resemble elongated, concentric ellipses. A requirement for a plain whorl is that an imaginary line, drawn from delta to delta, must cut through at least one recurving ridge (Figure 4.9). This distinguishes plain whorls from central pocket loop whorls, which will be discussed later.

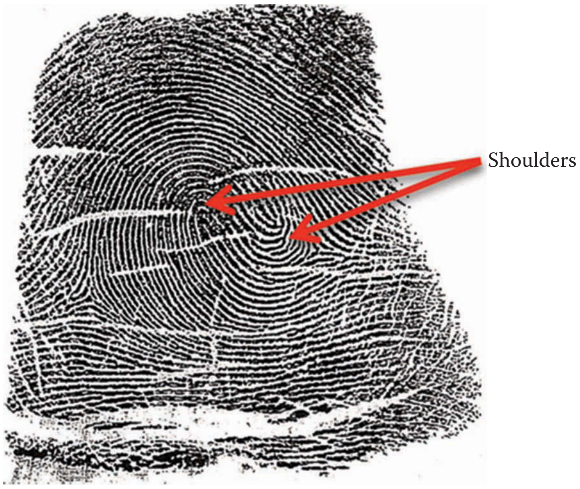


Figure 4.10 A double loop whorl with two distinct shoulders.

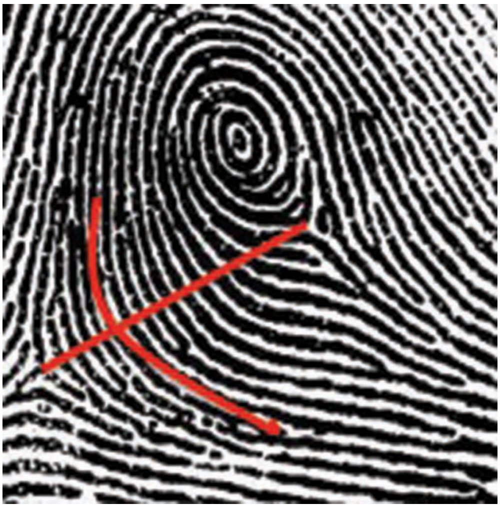


Figure 4.11 A central pocket loop whorl. A line from delta to delta does not cut through a recurving ridge.

Double-loop whorls are technically whorl patterns, since they have two deltas, but they consist of two distinct loops curved around each other like a yin-yang symbol, as illustrated in Figure 4.10. These two intertwined loops have two distinct shoulders (Figure 4.10). Double-loop whorls are most commonly found in the thumbs.

A *central pocket loop whorl* resembles a small whorl pattern trapped within a loop. There are, however, two deltas associated with this pattern, which is what makes it a whorl. It can be difficult to distinguish a central pocket loop whorl from a plain whorl. In a central pocket loop whorl, an imaginary line drawn from delta to delta does not cut through a recurving ridge (Figure 4.11).

An *accidental whorl*, otherwise known as an *accidental*, is any combination of two distinct pattern types. The accidental fits none of the definitions given earlier. This is the only pattern type in which you will see more than two deltas.[3] This pattern most often displays some combination of a loop and a whorl (Figure 4.12).

Whorls are further characterized by the proximity of their left and right deltas. This categorization is called *whorl tracing*, or following a friction ridge path from the left delta to a place opposite the right delta. As you trace the ridge, it may bifurcate (fork) or end. If either of these occurs, you can either follow the lower ridge of the bifurcation or drop down to the ridge below an ending ridge and continue tracing all the way to the right-hand delta. Then count the ridges between the tracing ridge and the delta.

Through the process of tracing, whorls can be classified as *inner* (I), *meet* (M), or *outer* (O) (Figure 4.13). The FBI's *Fingerprint Training Manual* describes this process as follows[3]:

- If there are three or more ridges inside the right delta, the tracing is an—I—inner.
- If there are three or more ridges outside the right delta, the tracing is an—O—outer.

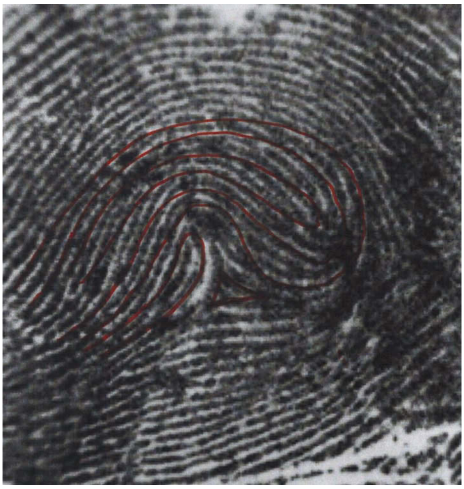
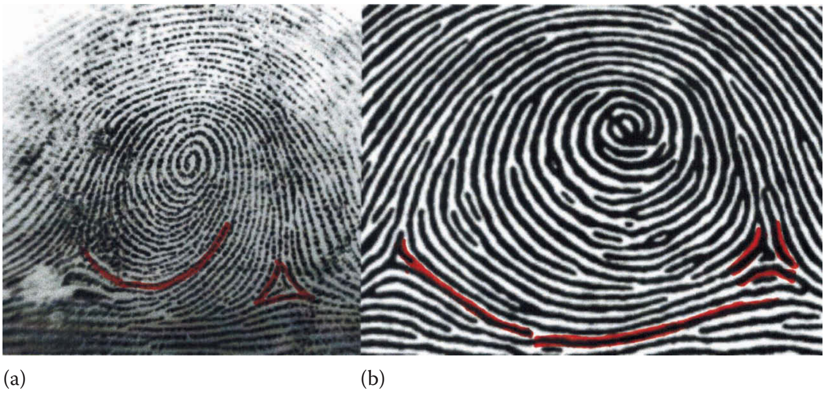


Figure 4.12 An accidental whorl pattern.



(a) (b)

Figure 4.13 Whorls demonstrating inner and outer tracing.

- If there are one or two ridges either inside or outside the right delta, or if the tracing stops on the right delta itself, the tracing is a—M—meet.

Tracing for whorls, such as ridge counting for loops, becomes important not only during a fingerprint examination, but also when you consider the classification formulas discussed in Section 4.5.

4.4 Arches

Arches are the least common fingerprint pattern type. Arches are found in approximately 5% of fingerprints in the general population. A fingerprint arch is similar to an architectural arch or a wave. The friction ridges enter one side of the fingerprint, make a rise in the center, and exit out the other side of the print. There are no deltas in an arch pattern and the core is indistinct in most arches. There are two types of arches: plain arches and tented arches.

Plain arches are characterized by a smooth arching pattern with all of the friction ridges rising and falling relatively uniformly through the pattern (Figure 4.14). It cannot have any looping ridges, recurves, or ridges angular to the wave pattern.[3]

Tented arches are arch patterns that contain one or more ridges at an angle to the flow of the arch, often perpendicular to the ridges at the base of the print. Another way to describe the tented arch is “a type of pattern which possesses either an angle, an upthrust, or two of the three basic characteristics of the loop.”[3] An *upthrust* is a vertical or angular protrusion in the center of the print that ends abruptly (Figure 4.15). A tented arch is also characterized as any pattern possessing two of the three requirements for a loop. Thus, it appears to be a loop, but it lacks either a delta, a recurve, or ridge count. For example, a fingerprint may possess a recurve and a delta, but no intervening ridge between the delta and core, as illustrated in Figure 4.16. This pattern, which at first glance resembles a loop, is a tented arch.

Knowledge of pattern types, cores, deltas, ridge counting, and whorl tracing is important when the classification schemes discussed below are taken into consideration. It is important to be able to distinguish a loop from a tented arch or a tented arch from a plain arch. While digital computer files are rapidly replacing the following classification systems, a fingerprint examiner should be able to analyze a fingerprint pattern without the assistance of a computer.

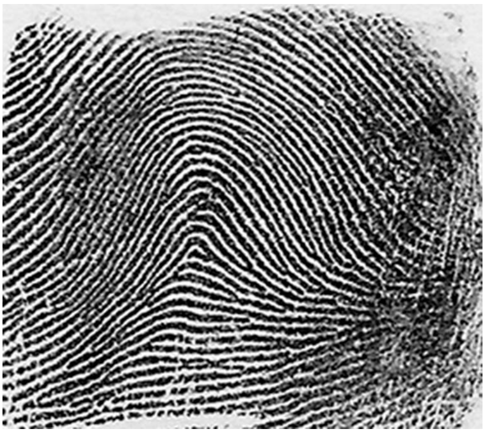


Figure 4.14 A plain arch.

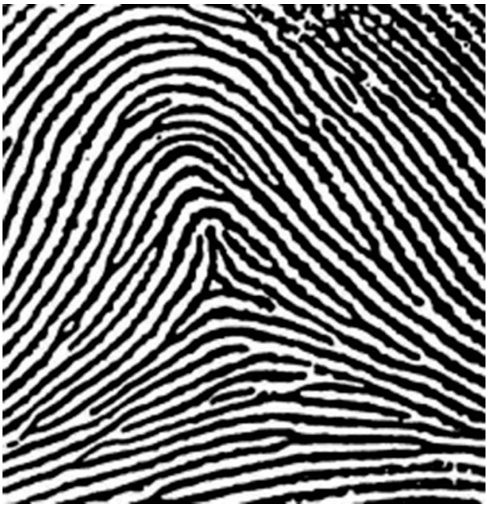


Figure 4.15 A tented arch with an upthrust.

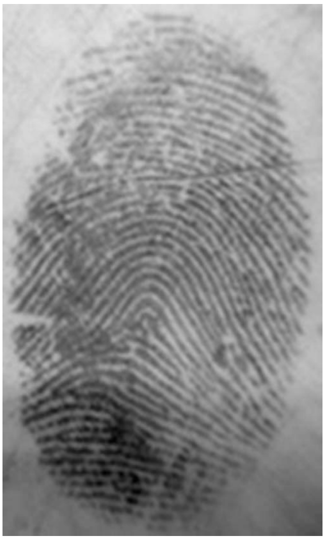


Figure 4.16 A tented arch with the appearance of a loop.

4.5 Fingerprint Classification

Classification is the process of coding and organizing large amounts of information or items into manageable, related subcategories or classes. A library classifies books both by organizing them by genre and author and by assigning alphanumerical designations according to the Dewey Decimal System. The number and letter combination on the spine of the book allows us to quickly and easily find one book in a library of thousands. Similarly, taxonomy is a method of classifying living organisms. Organisms are sorted into the following categories, by increasing selectivity: kingdom, phylum, class, order, family, genus, and species. An example of the taxonomic designation of the common house cat would be as follows: kingdom Animalia, phylum Chordata, class Mammalia, order Carnivora, family Felidae, genus *Felis*, and species *catus*.

Similarly, fingerprint classification is the process of organizing large volumes of fingerprint cards into smaller groups based on type: fingerprint patterns, ridge counts, and whorl tracings. When an individual is arrested, it is important to search the record fingerprint files for a duplicate of that fingerprint record to verify a recidivist's (repeat offender's) identity. In the mid-1800s, prior to the advent of fingerprint records, individuals were photographed for rogues' galleries, which were collections of mug shots. Bertillonage was another classification system based on anthropometric measurements, but it fell out of favor by the turn of the twentieth century. Many individuals give false names when arrested, or change their appearance, making the fingerprint record the only reliable verification of the arrestee's identity.

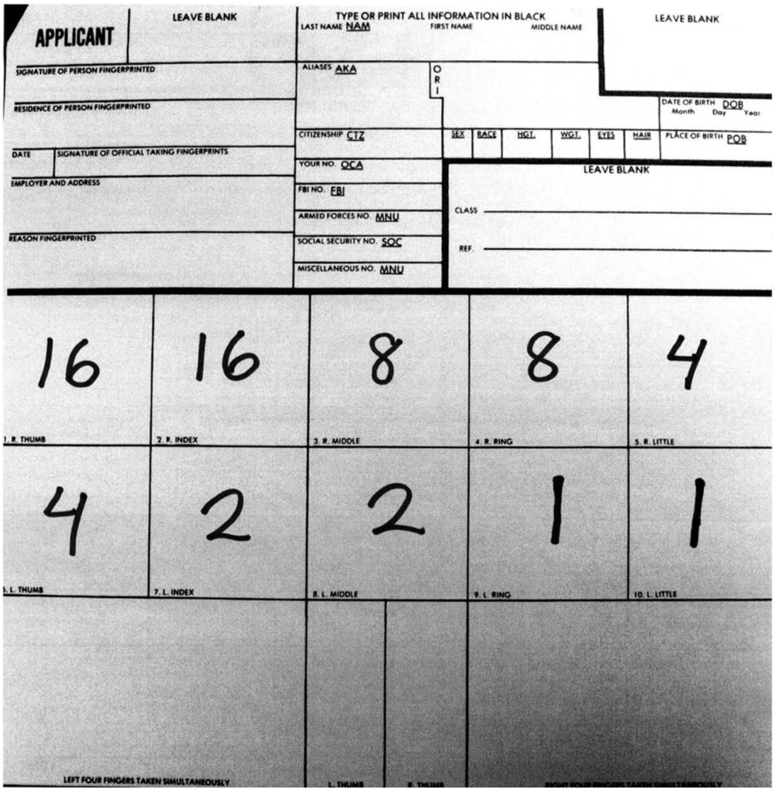
Fingerprints were historically stored in filing cabinets according to their alphanumeric classification designations. When an individual was arrested and fingerprinted, the fingerprint card was classified and the filing cabinets were searched according to that classification label. The advent of the *Automated Fingerprint Identification System* (*AFIS*), commonly known as the fingerprint computer, has mostly negated the need for manual classification and filing of hard copies of fingerprint records. Fingerprints are now recorded on a scanner (a "livescan" device) attached to a computer. They are stored digitally, just like digital photographs. However, similar to learning about the history of fingerprints, knowledge of historical classification systems gives the fingerprint examiner a better understanding of pattern types and the analysis of friction ridge impressions. Many employers, as well as fingerprint certification tests, require a working knowledge of the basic classification schemes addressed in the following sections.

4.6 Henry Classification

Sir Edward Henry, Azizul Haque, and Chandra Bose developed the *Henry Classification System* in 1897.[6] The Henry system became the most widely used classification system in English-speaking countries. Juan Vucetich also developed a classification system used in Spanish-speaking countries. Prior to the advent of both the Vucetich and Henry systems, Bertillon, Purkinje, Galton, and Faulds also worked on fingerprint classifications systems.[7] Classification systems have been modified and applied in countries such as Hungary, Portugal, Prague, Germany, Japan, Spain, Holland, Italy, Russia, Mexico, Egypt, Norway, Cuba, Chile, and France.[6]

Most of these systems involve analyzing the pattern types of the fingers and assigning alphanumeric designations to each finger. In both the Henry and Vucetich systems, the resulting classification resembles a fraction, with a numerator above a classification line and a denominator below the classification line. There may be several sets of letters (both upper and lower case) and numbers both above and below the classification line.

There are six components, or parts, to the Henry Classification System: the *primary*, *secondary*, *subsecondary*, *major*, *final*, and *key*. This text focuses on examples of primary



APPLICANT

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TYPE OR PRINT ALL INFORMATION IN BLACK
LAST NAME NAM FIRST NAME MIDDLE NAME

LEAVE BLANK

SIGNATURE OF PERSON FINGERPRINTED

ALIASES AKA

ORI

RESIDENCE OF PERSON FINGERPRINTED

DATE OF BIRTH DOB
Month Day Year

CITIZENSHIP CTZ

SEX RACE HGT. WGT. EYES HAIR

PLACE OF BIRTH POB

DATE

SIGNATURE OF OFFICIAL TAKING FINGERPRINTS

YOUR NO. OCA

LEAVE BLANK

EMPLOYER AND ADDRESS

FBI NO. FBI

CLASS

ARMED FORCES NO. MNU

REASON FINGERPRINTED

SOCIAL SECURITY NO. SOC

REF.

MISCELLANEOUS NO. MNU

16 1. R. THUMB	16 2. R. INDEX	8 3. R. MIDDLE	8 4. R. RING	4 5. R. LITTLE
4 6. L. THUMB	2 7. L. INDEX	2 8. L. MIDDLE	1 9. L. RING	1 10. L. LITTLE

LEFT FOUR FINGERS TAKEN SIMULTANEOUSLY

L. THUMB

R. THUMB

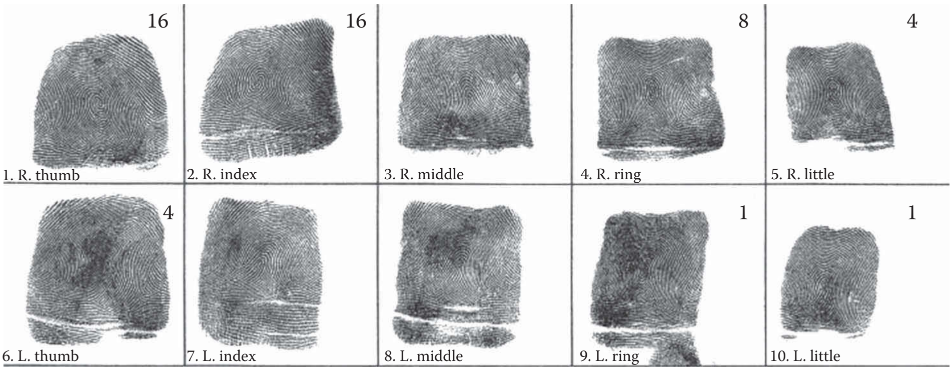
RIGHT FOUR FINGERS TAKEN SIMULTANEOUSLY

Figure 4.17 The point values assigned to each finger using the Henry Classification system.

classification. Primary classification assigns numerical value to only the whorl patterns present in the fingerprint record. It is written as a fraction, but unlike a fraction, it is never reduced. One number will appear in the numerator, and one number will appear in the denominator. The fraction line is known as the classification line.

Each finger is numbered from 1 to 10, starting with the right thumb as finger number one, proceeding through the right index, right middle, right ring, and right little fingers. The left thumb is finger number six, followed by the left index, left middle, left ring, and left little fingers. The fingerprint card, also known as a *tenprint card*, is numbered 1–10. The fingers are each assigned a point value if a whorl is found on that finger. The point values decrease by half as you proceed through the remaining eight. (Figure 4.17) For example, if there is a whorl located on the number one finger (the right thumb), it is assigned a value of 16. If there is a whorl located on the number eight finger (the left middle finger), it is assigned a value of two.

The numerator is the sum of the point values for the *even* numbered fingers plus one. The denominator is the sum of the point values for the *odd* numbered fingers plus one. The number one is added to both the top and bottom values in order to avoid a fraction that reads 0/0. Therefore, if there are no whorls present in any of the 10 fingers, the primary classification is 1/1 rather than 0/0. If every finger on the tenprint card is a whorl pattern, the primary classification is 32/32. There are, in fact, 1024 possible variants of the primary classification component of the formula. Figure 4.18 is an example of how to find the primary classification from a tenprint card (Figure 4.18).



#1 = 16
#2 = 16
#3 = Loop
#4 = 8
#5 = 4

#6 = 4
#7 = Loop
#8 = Loop
#9 = 1
#10 = 1

$$\frac{\text{Even \#s (+1)}}{\text{Odd \#s (+1)}} = \frac{16+8+4+1\ (+1)}{16+4+1\ (+1)} = \frac{30}{22}$$

Figure 4.18 An example of primary Henry Classification.

4.7 NCIC Classification

The *National Crime Information Center (NCIC)*, a division of the FBI's Criminal Justice Information Services (CJIS), is a national repository of computerized criminal justice information. It was created in 1965 during the J. Edgar Hoover era and has since been expanded and upgraded to its current incarnation, NCIC 2000, which launched in 1999.[8,9] NCIC is accessible by criminal justice agencies in all 50 states, Washington, DC, Puerto Rico, Guam, the U.S. Virgin Islands, and Canada.[10] It includes 21 databases that include such information as criminal records, missing persons, the sex offender registry, stolen property records, fugitive records, orders of protection, and suspected terrorist activity.[10] As of 2011, the FBI reported 11.7 million active records.[10] The goal of NCIC is to provide an investigative tool not only to identify property but also to protect law enforcement personnel and the public from individuals who may be dangerous.

NCIC also includes its own fingerprint classification information. It is important to understand NCIC classification in order to decipher these codes if you work in any capacity within the criminal justice system. The NCIC fingerprint classification system applies a two-letter code to each pattern type. The two-letter codes for each of the 10 fingers are combined to form a 20-character classification. Each fingerprint's code is listed in sequence, from the number 1 finger (right thumb) to the number 10 finger (left little finger). Ridge counts of loops and whorl tracings are also included in the coding system to further classify pattern types. Table 4.1 lists the NCIC classification codes.

If an individual has plain whorls with a meet tracing on fingers 2–10 and a double-loop whorl with an outer tracing on finger number 1, the NCIC classification would read as follows:

dOPMPMPMPM
PMPMPMPMPM

Table 4.1 NCIC Classification Codes

Pattern Type	NCIC Code
Ulnar loop ridge count	01–49
Radical loop ridge count + 50	51–99
Plain arch	AA
Tented arch	TT
Plain whorl, inner tracing	PI
Plain whorl, outer tracing	PO
Plain whorl, meet tracing	PM
Double loop whorl, inner tracing	dI
Double loop whorl, outer tracing	dO
Double loop whorl, meet tracing	dM
Central pocket loop whorl, inner tracing	CI
Central pocket loop whorl, outer tracing	CO
Central pocket loop whorl, meet tracing	CM
Accidental, inner tracing	XI
Accidental, outer tracing	XO
Accidental, meet tracing	XM
Mutilated or extensively scarred	SR
Amputation	XX

The NCIC classification of an individual with plain whorls (outer tracing) on his or her thumbs and plain arches on his or her remaining fingers would be

POAAAAAAAA
POAAAAAAAA

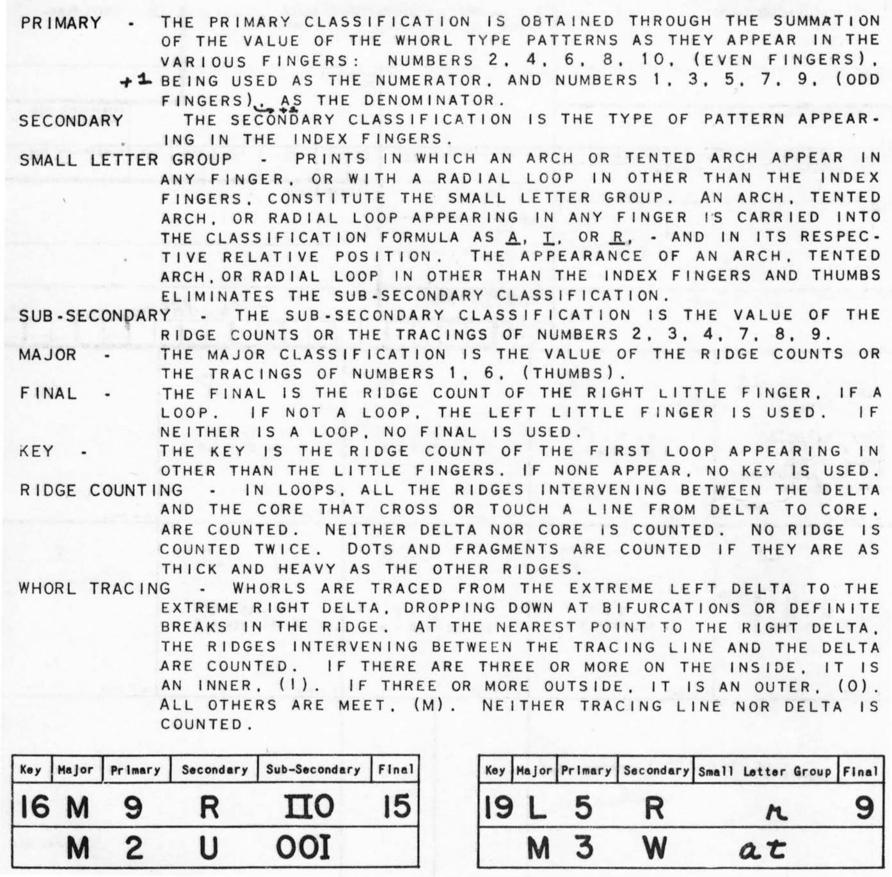
NCIC is unique in that it does not include the actual fingerprint images. It only includes the classification described previously. A working knowledge of NCIC fingerprint classification codes can give you a wealth of information regarding the fingerprint patterns of the individual queried in an NCIC search, which can include a tentative identification of a person of interest such as a suspect or a missing person.

4.8 I Had a Case: The FBI in the 1970s

(Submitted by Mike Stapleton, Stapleton & Associates, Ret. FBI)

Imagine for a moment that you are a Fingerprint Technician working at the United States Federal Bureau of Identification (FBI), Identification Division in 1970. You are assigned to search an incoming tenprint card in the criminal file system consisting of approximately 34 million individuals to determine if the suspect had a prior record. There is only one problem. AFIS does not exist yet! You are going to have to conduct the search by hand in a six-story building that is a city block in circumference. The FBI generally receives 30,000 tenprint cards per day to search so you are going to have to work fast. This seems like an impossible task. How will you conduct your search? How will you be able to identify a prior record?

Fortunately, the FBI has given you 12 weeks of very detailed and extensive classroom training in classifying fingerprints according to the Henry Classification System (with some



PRIMARY - THE PRIMARY CLASSIFICATION IS OBTAINED THROUGH THE SUMMATION OF THE VALUE OF THE WHORL TYPE PATTERNS AS THEY APPEAR IN THE VARIOUS FINGERS: NUMBERS 2, 4, 6, 8, 10, (EVEN FINGERS), +1 BEING USED AS THE NUMERATOR, AND NUMBERS 1, 3, 5, 7, 9, (ODD FINGERS), AS THE DENOMINATOR.

SECONDARY THE SECONDARY CLASSIFICATION IS THE TYPE OF PATTERN APPEARING IN THE INDEX FINGERS.

SMALL LETTER GROUP - PRINTS IN WHICH AN ARCH OR TENTED ARCH APPEAR IN ANY FINGER, OR WITH A RADIAL LOOP IN OTHER THAN THE INDEX FINGERS, CONSTITUTE THE SMALL LETTER GROUP. AN ARCH, TENTED ARCH, OR RADIAL LOOP APPEARING IN ANY FINGER IS CARRIED INTO THE CLASSIFICATION FORMULA AS A, T, OR R, - AND IN ITS RESPECTIVE RELATIVE POSITION. THE APPEARANCE OF AN ARCH, TENTED ARCH, OR RADIAL LOOP IN OTHER THAN THE INDEX FINGERS AND THUMBS ELIMINATES THE SUB-SECONDARY CLASSIFICATION.

SUB-SECONDARY - THE SUB-SECONDARY CLASSIFICATION IS THE VALUE OF THE RIDGE COUNTS OR THE TRACINGS OF NUMBERS 2, 3, 4, 7, 8, 9.

MAJOR - THE MAJOR CLASSIFICATION IS THE VALUE OF THE RIDGE COUNTS OR THE TRACINGS OF NUMBERS 1, 6, (THUMBS).

FINAL - THE FINAL IS THE RIDGE COUNT OF THE RIGHT LITTLE FINGER, IF A LOOP. IF NOT A LOOP, THE LEFT LITTLE FINGER IS USED. IF NEITHER IS A LOOP, NO FINAL IS USED.

KEY - THE KEY IS THE RIDGE COUNT OF THE FIRST LOOP APPEARING IN OTHER THAN THE LITTLE FINGERS. IF NONE APPEAR, NO KEY IS USED.

RIDGE COUNTING - IN LOOPS, ALL THE RIDGES INTERVENING BETWEEN THE DELTA AND THE CORE THAT CROSS OR TOUCH A LINE FROM DELTA TO CORE, ARE COUNTED. NEITHER DELTA NOR CORE IS COUNTED. NO RIDGE IS COUNTED TWICE. DOTS AND FRAGMENTS ARE COUNTED IF THEY ARE AS THICK AND HEAVY AS THE OTHER RIDGES.

WHORL TRACING - WHORLS ARE TRACED FROM THE EXTREME LEFT DELTA TO THE EXTREME RIGHT DELTA, DROPPING DOWN AT BIFURCATIONS OR DEFINITE BREAKS IN THE RIDGE. AT THE NEAREST POINT TO THE RIGHT DELTA, THE RIDGES INTERVENING BETWEEN THE TRACING LINE AND THE DELTA ARE COUNTED. IF THERE ARE THREE OR MORE ON THE INSIDE, IT IS AN INNER, (I). IF THREE OR MORE OUTSIDE, IT IS AN OUTER, (O). ALL OTHERS ARE MEET, (M). NEITHER TRACING LINE NOR DELTA IS COUNTED.

Key	Major	Primary	Secondary	Sub-Secondary	Final
16	M	9	R	IIO	15
	M	2	U	OOI	

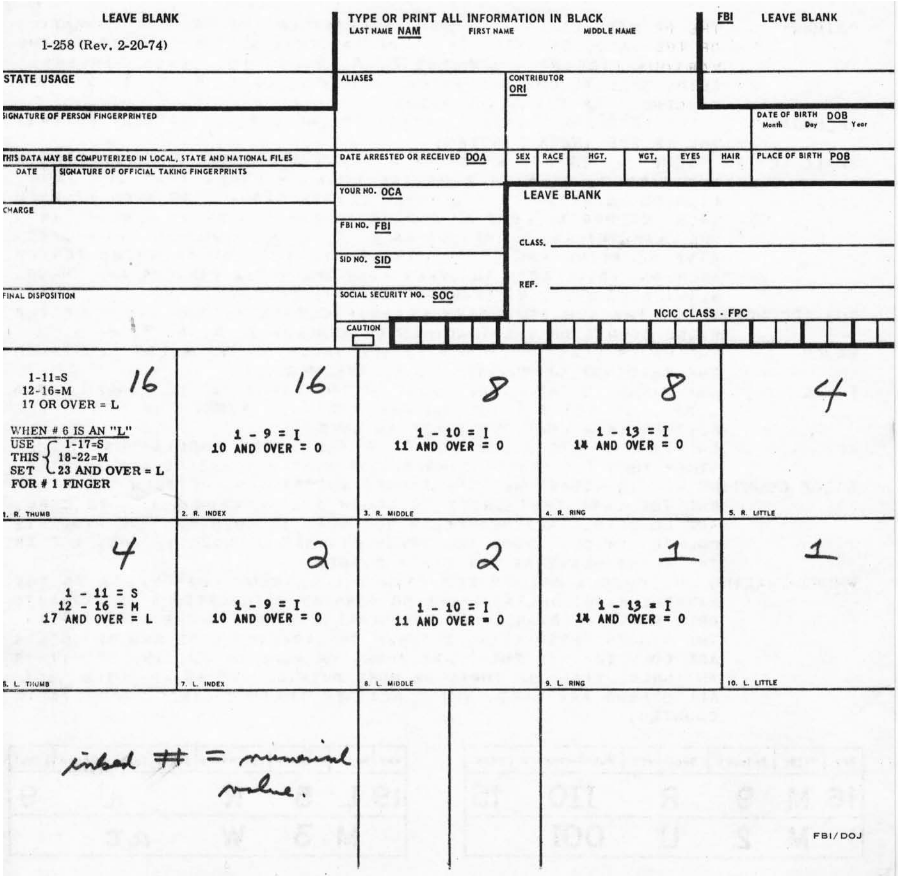
Key	Major	Primary	Secondary	Small Letter Group	Final
19	L	5	R	r	9
	M	3	W	at	

Figure 4.19 The United States Federal Bureau of Investigation's guidelines describing the full Henry Classification formula.

modifications by the FBI). When you successfully complete this course of study, you possess the knowledge, skills, and ability to classify, search, and identify fingerprints in the FBI's massive file system (Figures 4.19 and 4.20 illustrate the FBI's guidelines for how to determine the full Henry classification formula from a tenprint card.)

Classification means that you ridge counted the loop patterns, located any arch or tented arch patterns, and identified the types of whorl patterns with tracings with 100% accuracy. Lastly, you interpret your results to arrive at the Henry Classification formula. You then use that formula to direct you to where you need to go in that huge building to conduct your search. With all this training, you arrive at a point where you can accurately classify a tenprint card and complete your search in about 10 min to either locate a prior record or determine there is no prior record.

For 8 h per day you stand at file cabinets and flip through tenprint cards in an effort to determine if someone has a prior record. Your job requires you to classify and search six cards per hour on average. After preforming these tasks for a month, you receive your first paycheck in the amount of $125. How do you pay rent and still eat in Washington, DC with $125? In 1970, the Identification Division had approximately 2,000 employees and many of them managed somehow.



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1-258 (Rev. 2-20-74)

TYPE OR PRINT ALL INFORMATION IN BLACK
LAST NAME NAM FIRST NAME MIDDLE NAME

FBI **LEAVE BLANK**

STATE USAGE

ALIASES

CONTRIBUTOR ORI

SIGNATURE OF PERSON FINGERPRINTED

DATE OF BIRTH DOB Month Day Year

THIS DATA MAY BE COMPUTERIZED IN LOCAL, STATE AND NATIONAL FILES

DATE

SIGNATURE OF OFFICIAL TAKING FINGERPRINTS

DATE ARRESTED OR RECEIVED DOA

SEX	RACE	HGT.	WGT.	EYES	HAIR	PLACE OF BIRTH POB

CHARGE

YOUR NO. OCA

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FBI NO. FBI

CLASS.

SID NO. SID

REF.

FINAL DISPOSITION

SOCIAL SECURITY NO. SOC

CAUTION ☐

NCIC CLASS - FPC

1-11=S 12-16=M 17 OR OVER = L 16 WHEN # 6 IS AN "L" USE THIS SET FOR # 1 FINGER: 1-17=S, 18-22=M, 23 AND OVER = L 1. R. THUMB	16 1 - 9 = I 10 AND OVER = 0 2. R. INDEX	8 1 - 10 = I 11 AND OVER = 0 3. R. MIDDLE	8 1 - 13 = I 14 AND OVER = 0 4. R. RING	4 5. R. LITTLE
4 1 - 11 = S 12 - 16 = M 17 AND OVER = L 6. L. THUMB	2 1 - 9 = I 10 AND OVER = 0 7. L. INDEX	2 1 - 10 = I 11 AND OVER = 0 8. L. MIDDLE	1 1 - 13 = I 14 AND OVER = 0 9. L. RING	1 10. L. LITTLE

inked # = numerical value.

FBI/DOJ

Figure 4.20 The United States Federal Bureau of Investigation's guidelines illustrating how to determine the full Henry Classification formula from a tenprint card.

4.9 Chapter Summary

There are three basic fingerprint pattern types: loops, whorls, and arches. Loops are the most common pattern type in the general population. A loop is a pattern in which friction ridges enter on one side of the finger, make a U-turn around a core, and flow out the same side of the finger. There are two types of loops: ulnar loops and radial loops. Loops can be further characterized by a ridge count from the delta to the core. Whorls are patterns in which the ridges make a complete circuit. They are the second most populous fingerprint patterns in the population. Whorls have at least two deltas and can be further characterized by whorl tracing. There are four subcategories of whorls: plain whorls, double-loop whorls, central pocket loop whorls, and accidentals. Arches are the least common fingerprint pattern type. They are patterns in which the ridges enter on one side of the finger, make a rise or wave in the center, and flow out the other side. There are two types of arches: plain arches and tented arches.

Classification systems categorize fingerprint records according to the pattern types found on the fingers. The Henry classification uses alphanumeric designations for fingerprint pattern types and lists them above and below a classification line. NCIC classification is a system that applies a two-letter code to each fingerprint pattern type.

4.10 Review Questions

1. List the three basic fingerprint pattern types.
2. Which fingerprint pattern type is the least common?
3. Which fingerprint pattern type is the most common?
4. How many deltas are most often observed in the arch, loop, and whorl patterns?
5. What are the three requirements of a loop pattern?
6. What are the four subcategories of whorls?
7. How do you "trace" a whorl, and what are the three possible types of whorl tracings?
8. What makes a tented arch different from a plain arch?
9. What is the primary Henry classification of an individual with whorls on his right and left thumbs and index fingers?
10. What is the primary Henry classification for an individual with the following NCIC classification code:

dM7017AA12
dM7219TT16

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Known Fingerprints

5

LEARNING OBJECTIVES

- Name the three methods of recording friction ridge skin.
- Understand the advantages and disadvantages of each process.
- Describe the various methods for recording known prints from decomposing skin.

5.1 Known Fingerprints

In order to analyze friction ridge skin, one must first record the pattern with fingerprint ink, fingerprint powder, or with a digital fingerprint scanner. The resulting fingerprint records are known as *exemplars* or *known prints*. They are also referred to as *inked prints*, *record prints*, or *standards*.[1] Known fingerprints are recorded for the following four reasons:

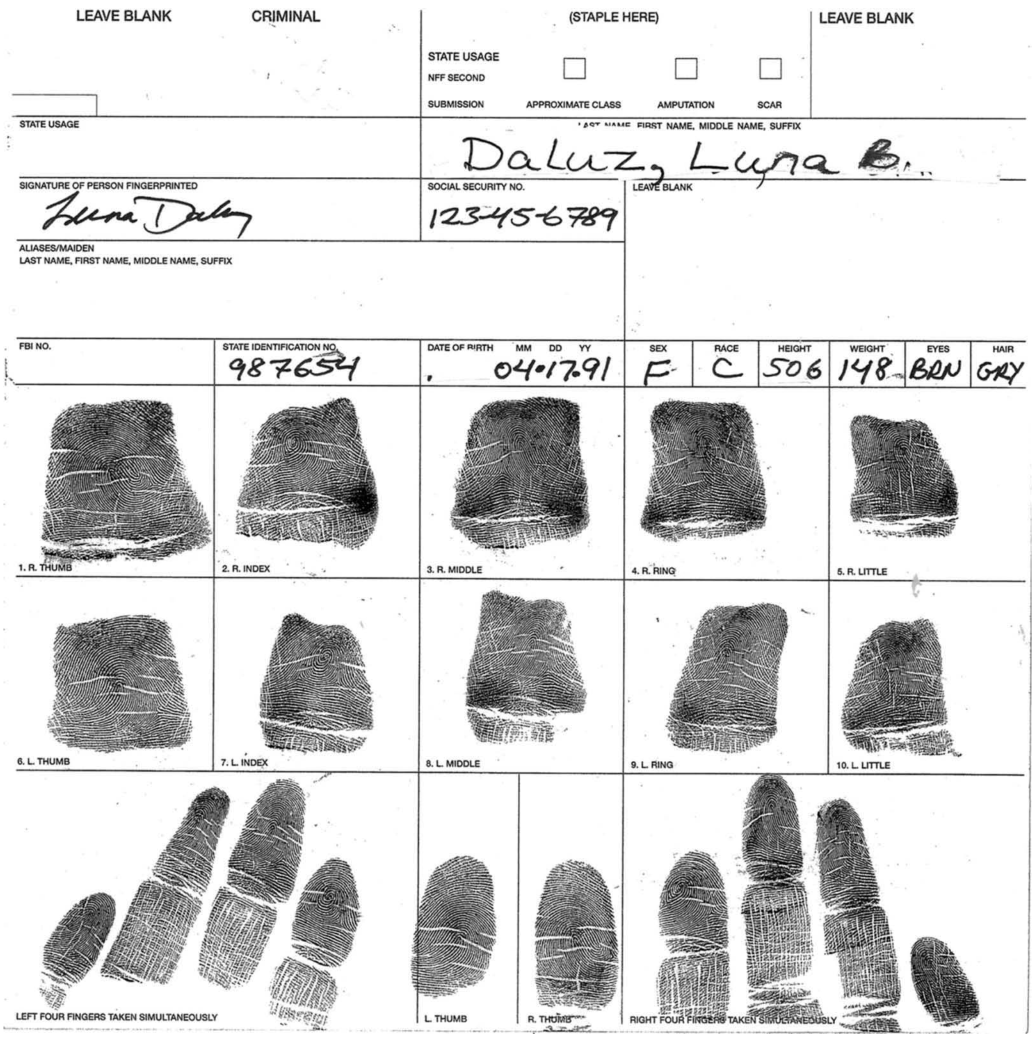
1. To serve as an official record of a person's identity
2. To search for a prior arrest record
3. To compare with evidentiary fingerprints
4. To input into the Automated Fingerprint Identification System (AFIS) for subsequent searches

It is important to take comprehensive records of the friction ridge skin in order to provide the best possible exemplars for identification purposes.

Records of the friction ridge skin on the fingers, finger joints, palms, and even feet and toes may be required for identification purposes. Thorough records of all the friction ridge skin on the hand—fingers, finger tips, finger joints, the sides of the fingers, palms, and writer's palms (sides of the hands)—are known as *major case prints*. The three most common types of friction ridge exemplars are inked impressions, powdered impressions, and digital scanned impressions.

5.2 Inked Exemplars

Historically, the most common medium for recording friction ridge skin was ink and cardstock. Inked fingerprints are recorded on *tenprint cards*. Tenprint cards are 8″×8″ printed white cardstock formatted to official government specifications. A tenprint card, such as the card pictured in Figure 5.1, contains demographic information along with the fingerprints of each of ten fingers (Figure 5.1). Each finger is rolled in ink and



LEAVE BLANK CRIMINAL (STAPLE HERE) LEAVE BLANK

STATE USAGE
NFF SECOND
SUBMISSION ☐ APPROXIMATE CLASS ☐ AMPUTATION ☐ SCAR

STATE USAGE

LAST NAME FIRST NAME, MIDDLE NAME, SUFFIX: Daluz, Luna B.

SIGNATURE OF PERSON FINGERPRINTED: Luna Daluz

SOCIAL SECURITY NO.: 123-45-6789

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ALIASES/MAIDEN
LAST NAME, FIRST NAME, MIDDLE NAME, SUFFIX

FBI NO.	STATE IDENTIFICATION NO.	DATE OF BIRTH MM DD YY	SEX	RACE	HEIGHT	WEIGHT	EYES	HAIR
	987654	04.17.91	F	C	506	148	BRN	GRY

1. R. THUMB
2. R. INDEX
3. R. MIDDLE
4. R. RING
5. R. LITTLE
6. L. THUMB
7. L. INDEX
8. L. MIDDLE
9. L. RING
10. L. LITTLE

LEFT FOUR FINGERS TAKEN SIMULTANEOUSLY

L. THUMB

R. THUMB

RIGHT FOUR FINGERS TAKEN SIMULTANEOUSLY

Figure 5.1 A tenprint card containing both exemplars and demographic information.

subsequently rolled into the corresponding box on the tenprint card. The finger is rolled from “nail to nail” to capture the entire friction ridge surface. This means the finger must be rolled from one side of the finger (at the nail) all the way around to the other side of the nail (Figure 5.2). A fingerprint rolled from nail to nail should be roughly rectangular in shape (Figure 5.3).

The fingerprints should be rolled with the individual being fingerprinted standing slightly back from the table with an arm bent at an approximate 90° angle. When the thumb is rolled, the subject’s hand is rotated toward the body. When the fingers are rolled, the subject’s hand is rotated away from the body. This allows the hand to be manipulated from the point of most resistance to the point of least resistance. The individual taking the fingerprints controls the subject’s hand to ensure the most comprehensive fingerprint record is taken. If the subject attempts to assist by moving his own fingers, the prints may be smudged or incomplete.

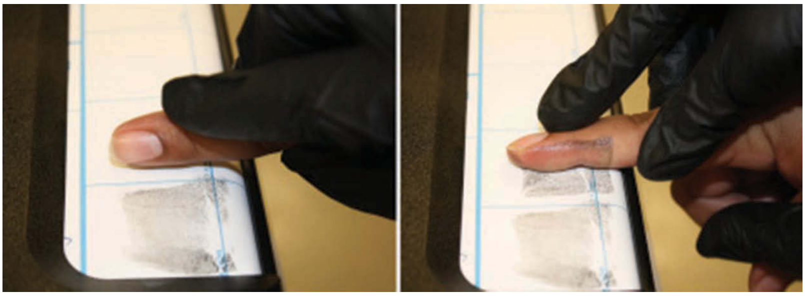


Figure 5.2 Rolling a fingerprint in ink onto a tenprint card.

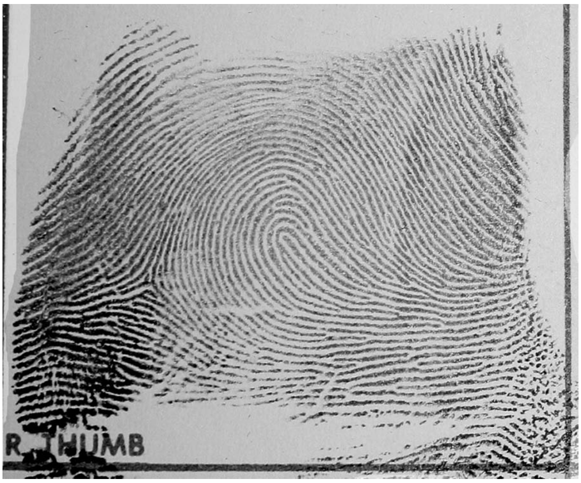


Figure 5.3 The rectangular shape of a comprehensive record of an inked fingerprint rolled from nail to nail.

A second copy of each fingerprint is recorded in the rectangular areas at the bottom of the fingerprint card. These impressions are known as the "flats." In the larger rectangles, the four fingers of the right hand and left hand are inked and recorded simultaneously from base to tip to record the friction ridges at the tip of the finger, which may have been missed in the rolled impressions. In the smaller rectangles at the bottom of the card, the thumbprints are also rolled from base to tip. These impressions are also known as *slaps* or *plain impressions*. The flats of the four fingers together are placed in the section of the tenprint card labeled "four fingers taken simultaneously." The sections designated for the flats of the thumbs are labeled "R. thumb" and "L. thumb." Ink is the traditional medium for recording fingerprints, palm prints, and major case prints. The following materials are used for recording fingerprints using ink (Figure 5.4):

- Gloves
- Ink pad (or a thin layer of printer's ink rolled out onto a glass slab)
- Tenprint card
- Fingerprint card holder
- Re-tabs (correction labels to amend errors made when recording the fingerprints)

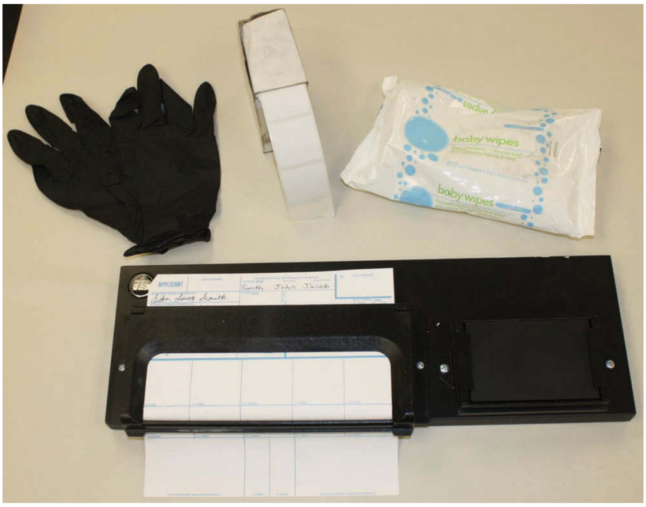


Figure 5.4 Materials for recording known fingerprints in ink onto a tenprint card.

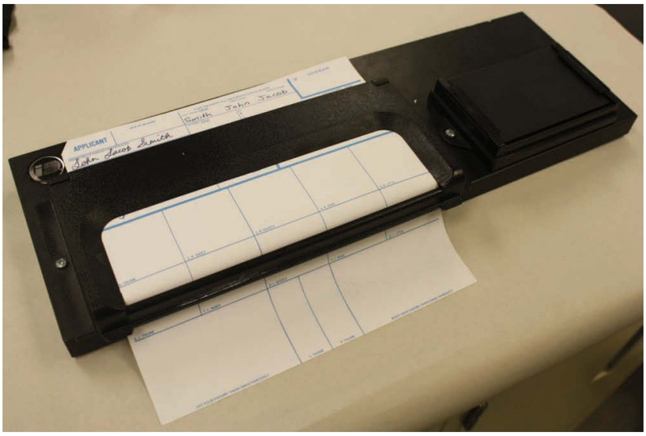


Figure 5.5 A tenprint card secured in a card holder.

The process of collecting rolled fingerprint records in ink from a suspect is as follows:

1. Set up the card in the card holder so the first row of boxes is clearly visible and the card is secure (Figure 5.5).
2. Take control of the subject's right hand.
3. Roll a thin layer of ink onto the right thumb, from nail to nail (Figure 5.6).
4. Roll the right thumb onto the corresponding box on the tenprint card with light, even pressure from nail to nail.
5. Repeat with the remaining fingers of the right and left hands (Figure 5.7).
6. Record the flats by pressing the four fingers of the right hand lightly onto the ink pad and rolling the fingers upward to ink the tips of the fingers (Figure 5.8).
7. Press the four fingers onto the flats section of the card with light pressure and roll the fingers upward to record the tips of the fingers (Figure 5.9).

8. Press the right thumb lightly to the ink pad and roll the thumb upward to ink the tip of the thumb.
9. Press the right thumb lightly to the area designated for the thumb flats and roll the thumb upward to record the ridge detail on the tip of the thumb (Figure 5.10).
10. Repeat this procedure for the left hand.

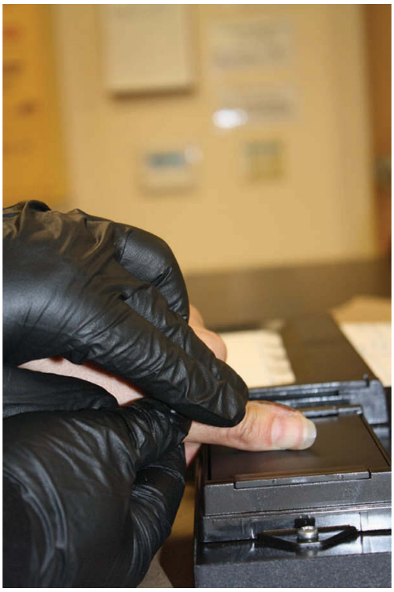


Figure 5.6 Rolling a thin layer of ink onto a subject's hand.

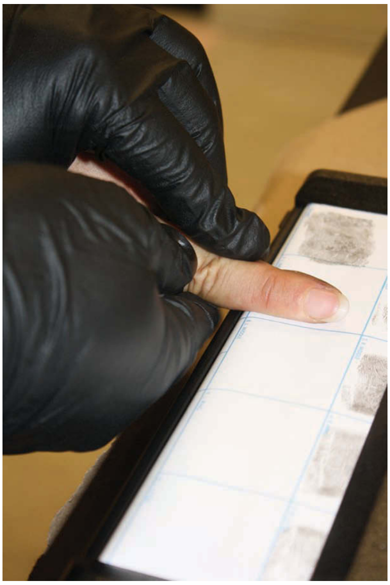


Figure 5.7 Rolling inked friction ridges onto a tenprint card.

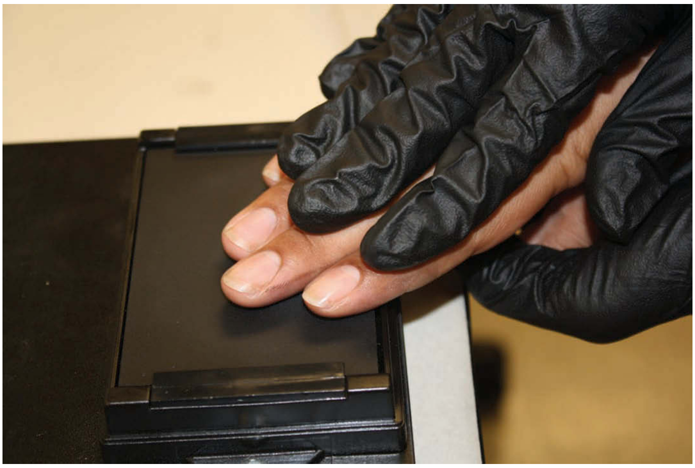


Figure 5.8 Simultaneously recording the four fingers of the hand onto a tenprint card.

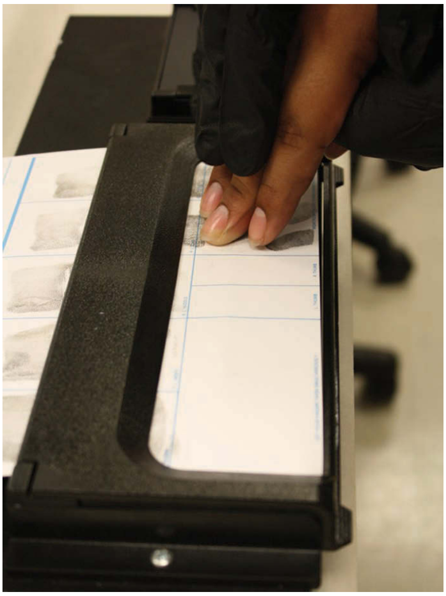


Figure 5.9 Rolling the inked fingers upwards to record the tips of the fingerprints on a tenprint card.

It may also be necessary to record the palm of the subject. The palm is coated with a light layer of ink and recorded on a white sheet of paper or a palm print card as shown in Figure 5.11. The *writer's palm*, the section of the meaty side of the hand that rests on a surface when one holds a pen or pencil, is also recorded. This area of the palm is known as the *hypothenar*.

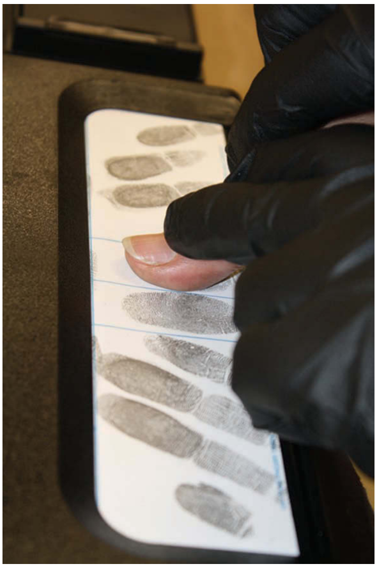
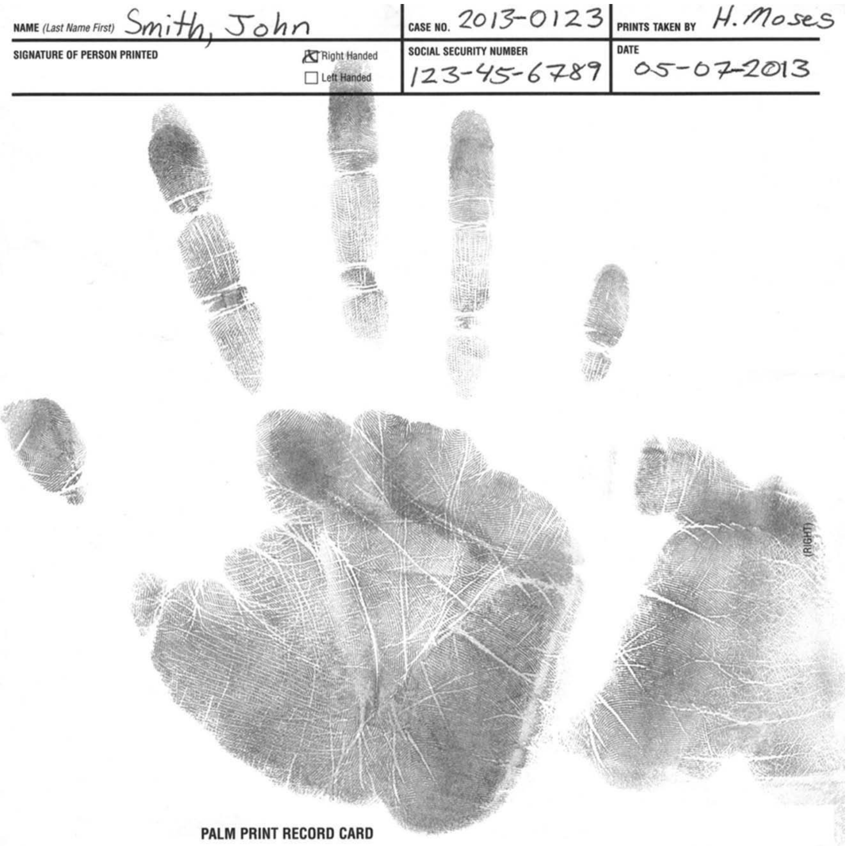


Figure 5.10 Recording the thumb on a tenprint card.



NAME (Last Name First) Smith, John
CASE NO. 2013-0123
PRINTS TAKEN BY H. Moses
SIGNATURE OF PERSON PRINTED
☒ Right Handed
☐ Left Handed
SOCIAL SECURITY NUMBER 123-45-6789
DATE 05-07-2013

(RIGHT)
PALM PRINT RECORD CARD

Figure 5.11 The inked palm print and writer's palm of the right hand.

5.3 Powdered Exemplars

Another medium for recording friction ridges requires the use of fingerprint powder. This method is quick and easy and results in high-quality major case prints. Unlike fingerprints recorded in ink, powdered friction ridges often display better detail including well-defined creases, ridge shapes, and pores. The hand is powdered and recorded on flexible, white adhesive sheets with clear acetate covers. These sheets, known as the *Handiprint System®*, are available from CSI Forensic Supply (formerly known as Kinderprint Co.).

The following materials are used for recording major case prints using fingerprint powder (Figure 5.12):

- Handiprint System® (white adhesive sheets and clear acetate covers)
- Black fingerprint powder
- Fiberglass fingerprint brush

The process of collecting major case prints in powder from a subject is as follows:

1. Peel the backing off of the white adhesive sheet and place the sheet on the table with the adhesive side facing upward (Figure 5.13).
2. Lightly powder the subject's hand using a standard fingerprint brush and a small amount of fingerprint powder (Figure 5.14).
3. Press the powdered hand to the adhesive sheet with fingers spread and turn the hand over (Figure 5.15).
4. Press the adhesive sheet to every section of the palm, hypothenar, finger joints, sides of finger joints, fingers, sides of fingers, and fingertips (Figure 5.16).
5. Pull the adhesive sheet from the subject's palm and place the sheet adhesive side up on the table (Figure 5.17).
6. Carefully place the clear acetate cover over the powdered print on the adhesive sheet taking care to avoid trapping air bubbles (Figure 5.18).
7. Record the subject's demographic information on the back of the acetate sheet.

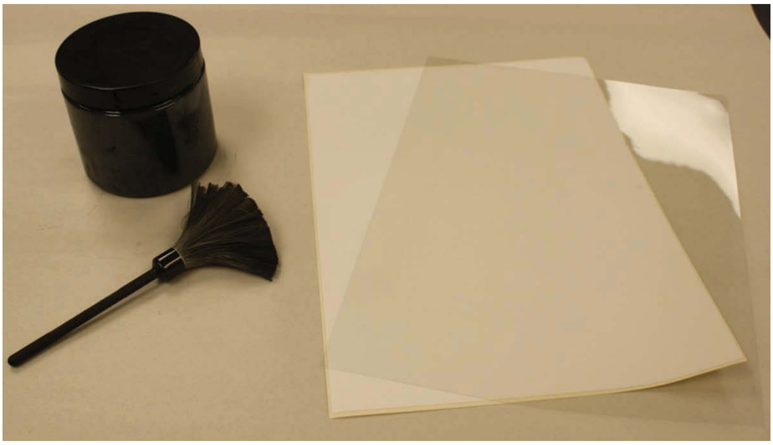


Figure 5.12 Supplies for recording major case prints using black fingerprint powder.

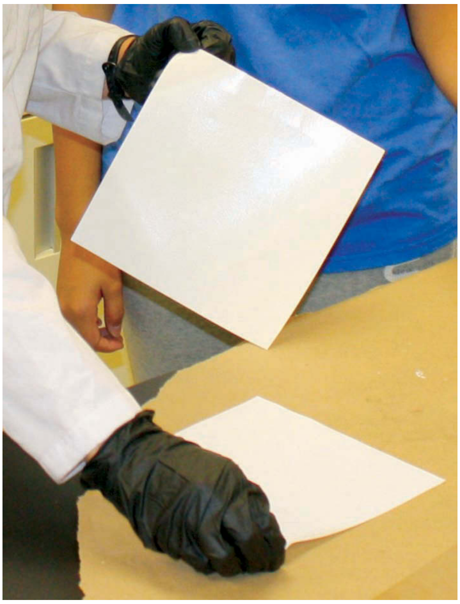


Figure 5.13 Preparing a white adhesive sheet for recording major case prints.

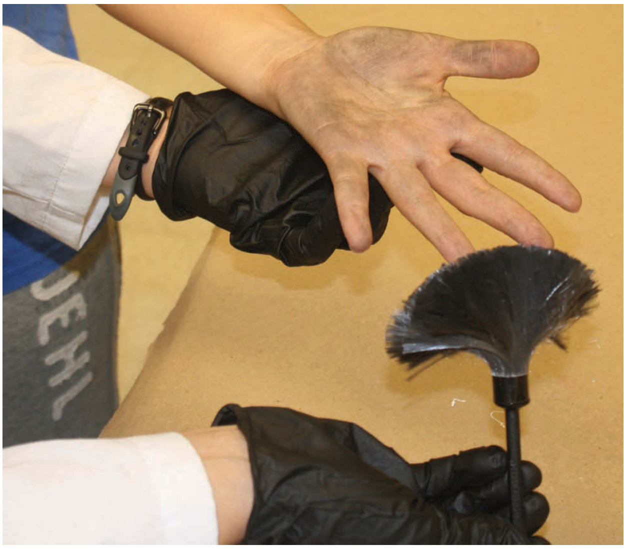


Figure 5.14 The subject's hand sufficiently coated with powder.

While this method is simple and results in high-quality major case prints, the resulting record is not in the official government format required for filing or for entry into an AFIS. For these purposes, a standard fingerprint or palm print card should be used. The powder method is often the best method for collecting exemplars to compare to evidentiary fingerprints when additional or previously unrecorded friction ridge detail is needed. This method is also effective for collecting exemplars from living victims as well as deceased persons.

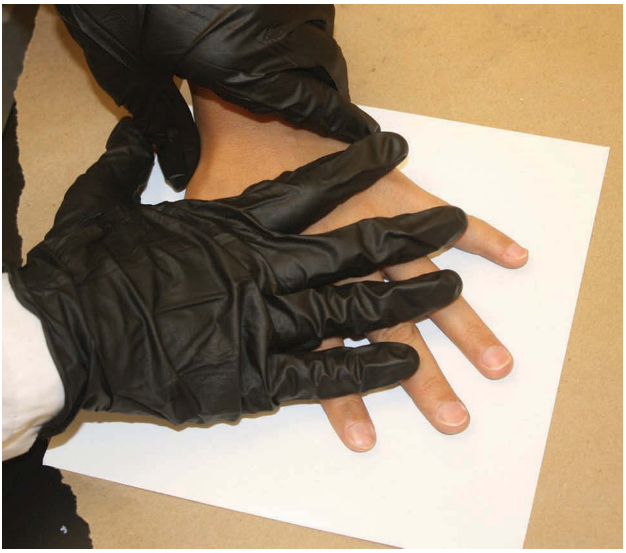


Figure 5.15 The subject's powdered hand pressed to the white adhesive sheet.

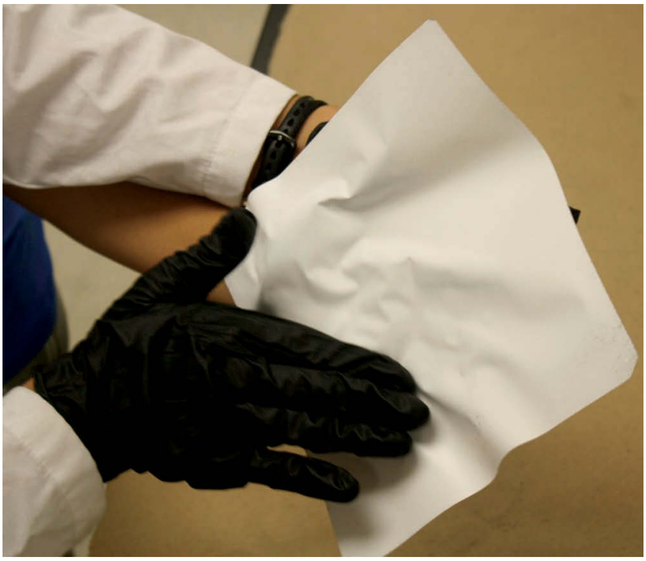


Figure 5.16 The adhesive sheet pressed onto all surfaces of the hand.

5.4 Digital Exemplars

Fingerprints are also recorded on a *livescan* device, which scans and digitizes fingerprints similar to a document scanner (Figure 5.19). This method does not require ink, powder, or any other medium to capture the print. The livescan operator, the individual taking the fingerprints, rolls the individual's fingerprints onto a plastic or glass plate in a manner similar to rolling inked prints onto a tenprint card. The resulting digital fingerprint image that appears on the computer screen resembles an inked impression on a tenprint card.

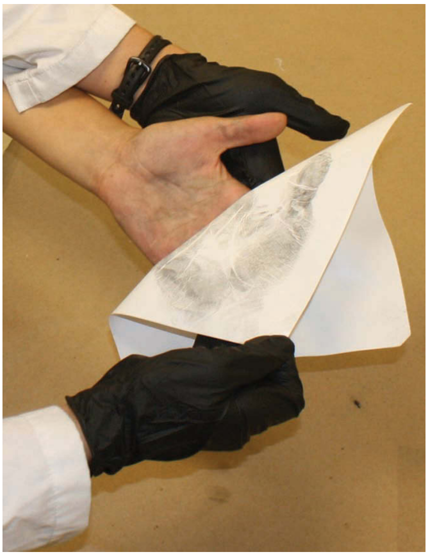


Figure 5.17 The white adhesive sheet peeled from the subject's hand.

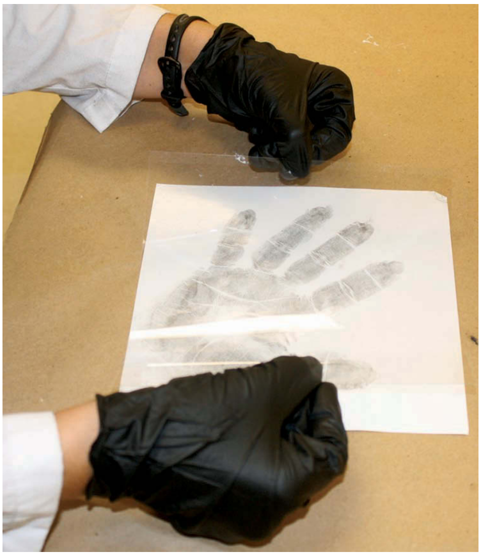


Figure 5.18 The clear acetate is mounted to the white adhesive sheet.

The livescan device acquires the image and the computer processes it using a computer *algorithm*: a set of procedures the computer follows to process data.

Livescan fingerprinting has several advantages over ink and powder methods and has mostly replaced these methods for the following reasons:

- Digital records are a cleaner method of recording friction ridges, as it does not require ink or powder.
- Livescan prints are digital and can be stored on computers rather than in the large numbers of filing cabinets required for tenprint cards.

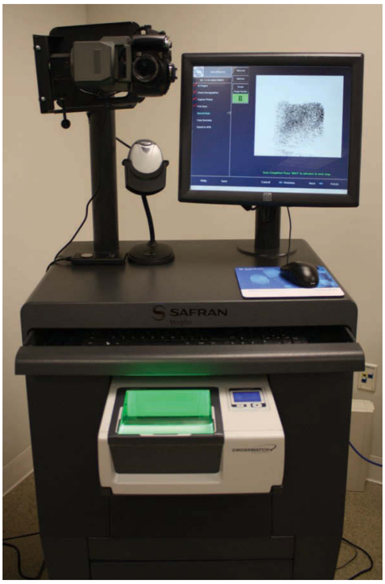


Figure 5.19 A livescan station with a camera, barcode scanner, computer monitor, keyboard, and glass plate for scanning friction ridge impressions.

- Unlimited numbers of exact copies of the prints can be reproduced on the computer printer.
- Livescan prints can be instantly transmitted between agencies using computer networks.
- Image quality is more uniform due to the quality control standards built into the livescan device.
- Livescan devices directly connect to AFIS. This makes it possible to take a person's prints; search them automatically against local, state, and national records; and return immediate results.

5.5 Fingerprints from Deceased Individuals

It is often necessary to collect postmortem exemplars from deceased individuals for identification purposes. In the case of the recently dead, fingerprint acquisition is a simple process. Ink or powder may be used to record the fingerprints. For inked fingerprints, postmortem print kits are available. They include fingerprint strips and a postmortem record strip holder, often referred to as a "spoon" (Figure 5.20). This tool makes it easier to roll the fingerprints of the corpse laid out in a supine position. The Handiprint System® may also be used for recording postmortem friction ridge skin utilizing fingerprint powder (Figure 5.21).

There are several challenges to fingerprinting individuals who are in more advanced stages of decomposition. One challenge occurs when the subject is in *rigor mortis*. Rigor mortis is the stiffening of the body, which can occur 2–4 h after death and develops fully

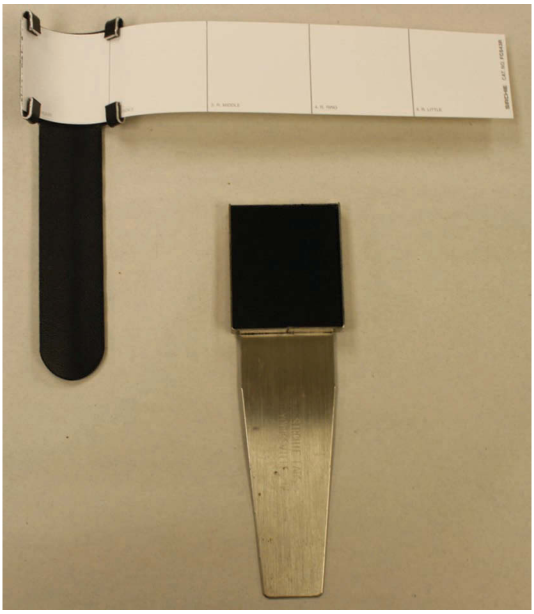


Figure 5.20 Materials for inking fingerprints of deceased individuals.

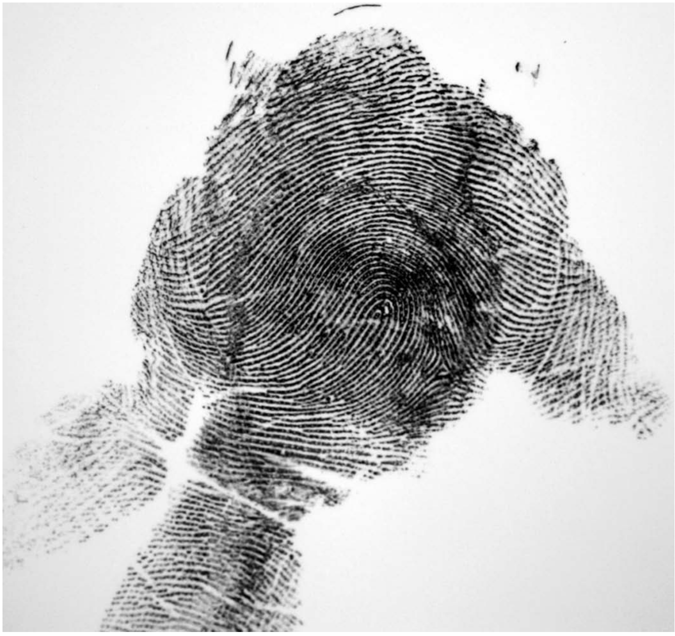


Figure 5.21 Powdered fingerprint from a deceased individual.

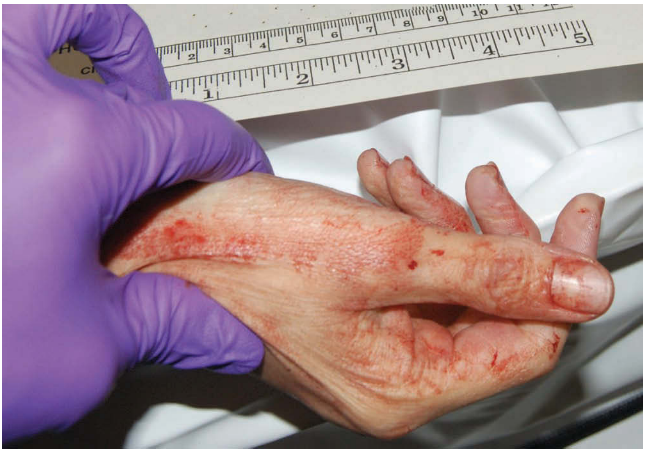


Figure 5.22 The fingers of this decedent are curled and stiffened by rigor mortis.

between 6 and 12h postmortem (Figure 5.22).[2] Rigor mortis occurs when metabolism stops with the cessation of cellular respiration after death.[2] Without adenosine triphosphate (ATP), the energy source for the body, the muscles can no longer contract. In this state, the deceased subject's hands are often completely stiff and inflexible. In this case, the rigor can be "broken" forcibly at each finger joint. The fingerprints can then be recorded using ink or powder.

Decomposing friction ridge skin undergoing putrefaction, maceration, or mummification presents a more challenging scenario. *Putrefaction* is the breakdown of the cells of the human body after death by bacteria and fungi. *Maceration* occurs when skin is submerged in water and the tissues become swollen.[1] Friction ridge skin may loosen from the dermal layer.[1] *Mummification* occurs when the skin is dehydrated. The friction ridge skin appears dry, leathery, and shriveled.

Putrefied friction ridge skin is fragile (Figure 5.23). It may be moist and peeling off in layers. Prior to attempting to ink or powder the finger, the area must be cleaned and dried.

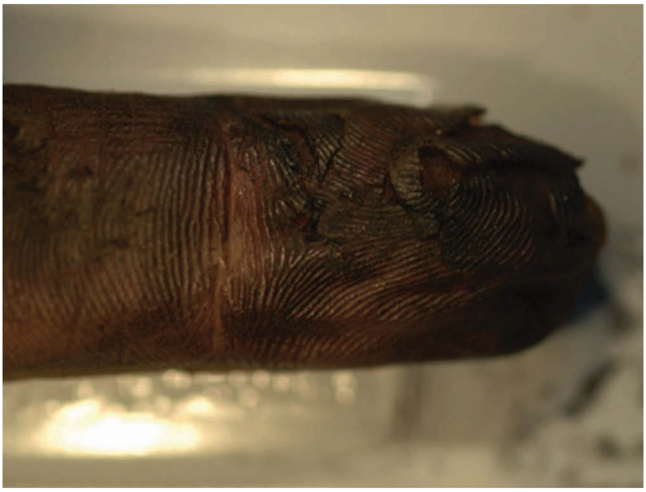


Figure 5.23 Burned and putrefied friction ridge skin.

At this point, it may be possible to ink the finger and collect useable fingerprints. If the skin is separating from the dermis, the recorder may choose to remove the skin and roll it with his gloved finger. This must be done with great care since the decomposing skin is fragile and tears easily. If the skin is too badly decomposed for these techniques, the fingers can be soaked in a 10% solution of formaldehyde.[1] Formaldehyde solution firms up the putrefied skin, after which it may be recorded with ink or powder.

Macerated skin may be swollen and wrinkled. It may be possible to clean, dry, and record the fingerprints in the usual manner using powder or ink. If the skin is too wrinkled, it may be stretched slightly in order to record more ridge detail. Another option for dealing with wrinkled skin is to inject glycerin or a product known as "tissue builder" under the skin.[1] This procedure puffs up the finger, thus eliminating the wrinkles. The liquid may leak, so it is recommended to tie a string or secure a rubber band just above the injection site.[1] If the skin is loosened from the dermis, it may be recorded similar to the putrefied skin by removing it and placing it on the recorder's gloved hand for rolling with ink.

Mummified skin, also referred to as *desiccated* skin, must be rehydrated prior to recording with ink or powder (Figure 5.24). The fingers can be severed from the hand and soaked in a 1%–3% solution of sodium hydroxide or potassium hydroxide for 24–48 h.[1] If the skin is peeling, the outer layers can be removed gently under warm running water with a soft-bristled toothbrush.[1] If the skin is stiff, the fingers may be soaked for a further 24–48 h in a solution of one tablespoon of dishwashing liquid in water.[1]

Recent research by Chen et al. and Schmidt et al. has shown that sodium carbonate is successful for rehydrating mummified remains.[3,4] Sodium carbonate (2.5 g) is mixed with 95% ethanol (79 ml) and distilled water (171 ml).[3,4] The fingers are allowed to soak for 24 h.[3,4] When the skin is rehydrated with any of the above techniques, the friction ridge skin is recorded with ink or powder.

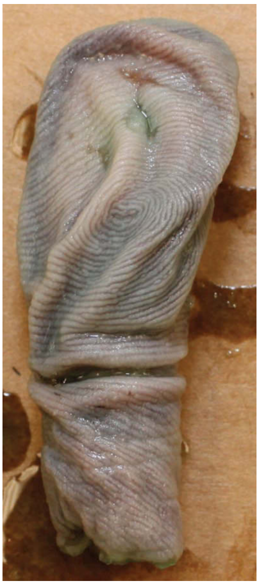


Figure 5.24 Mummified skin during the rehydration process.

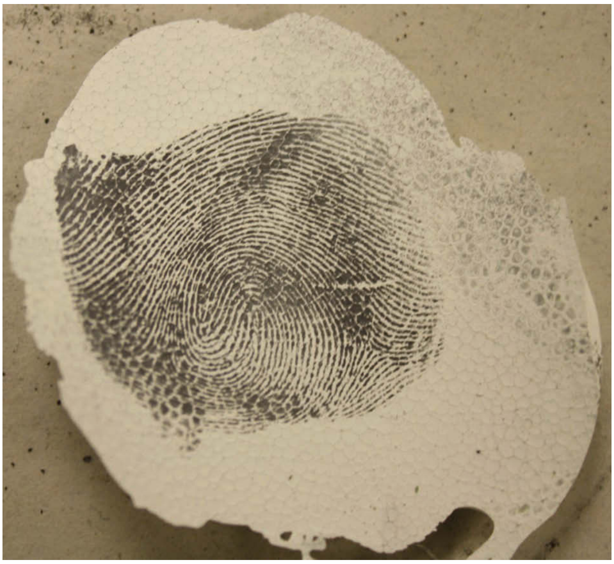


Figure 5.25 Silicone casting material with a black powdered fingerprint.

Decomposed skin may also be recorded using white silicone casting material. Fingerprint powder is applied to the clean, dry finger. The silicone casting material is mixed according to the manufacturer's directions and applied to the finger. When it hardens, it is gently peeled off the finger's surface (Figure 5.25). Regardless of the method utilized, great care should be exercised when working with fragile decomposing skin.

5.6 I Had a Case: Exemplar from a Charred Finger

A body was recovered from a suspected arson scene in Hawaii. The body was burned beyond recognition. The Medical Examiner's office was charged with the identification of the deceased individual. They detached the thumb from the victim and enlisted the help of a latent print examiner to obtain a usable exemplar for identification purposes. As the finger was charred and layered with dirt, the fingerprint examiner used a toothbrush to gently remove the loose outer layer of charred skin and debris. The finger was gently washed and dried thoroughly. The skin was fragile, so the best method for obtaining exemplars was to lightly powder the skin and apply a thick layer of silicone casting material.

When the silicone casting material was removed, a good quality exemplar was revealed. Since a fingerprint lifted with casting material is a reversed image, the exemplar was scanned on a flatbed scanner. The fingerprint examiner used an image processing computer program to reverse the image in order to return it to its proper orientation. The digital record was searched in AFIS and revealed the identity of the victim.

5.7 Chapter Summary

Known fingerprints—also referred to as exemplars, inked prints, record prints, or standards—are recorded for three reasons: to search for a match to a prior arrest record, to compare to unknown fingerprints from crime scenes or evidentiary items, or to input into the AFIS for subsequent searches. Exemplars may be recorded in ink, powder, or via livescan, a digital scanner. Exemplars are collected from deceased individuals to determine identity. Friction ridge skin in advanced stages of decay requires special handling depending on the type of decomposition present.

5.8 Review Questions

1. What are the three reasons for recording exemplar fingerprints?
2. What are major case prints?
3. Why is it important to roll fingerprints from "nail to nail"?
4. Why is it important to record the tips of the fingerprints in the section of the ten-print card where the flats are recorded?
5. What details may be seen more clearly when exemplars are recorded with powder rather than with ink?
6. What is livescan?
7. What are some of the advantages of livescan over inked methods?
8. How are deceased individuals in rigor mortis fingerprinted?
9. How is putrefied friction skin recorded?
10. How is mummified friction ridge skin recorded?

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The Nature of Latent Prints

6

> With dramatic suddenness he struck a match, and by its light exposed a stain of blood upon the whitewashed wall. As he held the match nearer, I saw that it was more than a stain. It was the well-marked print of a thumb.
>
> **Sir Arthur Conan Doyle**[1]

LEARNING OBJECTIVES

- Describe and give an example of latent, patent, and plastic fingerprints.
- Explain the duties of a latent fingerprint examiner.
- List the components of latent fingerprint residue.
- Explain why the challenges inherent in aging a latent print.
- Understand touch DNA and how to avoid contamination.

6.1 Latent Prints

Friction ridge impressions recovered from crime scenes or evidentiary items are known as *latent prints*. The word "latent" is from the Latin word meaning "hidden." The Merriam-Webster dictionary defines it as follows: "present and capable of emerging or developing but not now visible, obvious."[2] Latent prints are invisible friction ridge impressions of unknown origin. Evidentiary fingerprints are often referred to simply as *latents*, whether or not they are truly invisible.

There are a multitude of methods for recovering latent friction ridge impressions from items of evidence or from surfaces at crime scenes. These methods include the use of various powders, powder suspensions, and chemical reagents and are discussed in depth in Chapters 8–13 (Figure 6.1).

Not all fingerprints found at crime scenes are invisible. *Patent* prints are fingerprints that are visible to the naked eye. The word "patent" means "readily visible or intelligible: obvious."[2] Patent prints are visible because they are recorded in a visible medium such as blood, paint, or grease. Though patent prints are visible, they often require chemical processing to improve contrast. For example, a bloody fingerprint is often light brown or rust in color. A chemical reagent is applied to turn the light brown fingerprint a blue/black color so it is easier to see and photograph (Figure 6.2).

Plastic prints are those left in a soft material such as clay, glue, wax, soap, or tacky paint. The ridge detail is visible, but must be photographed to capture the details (Figure 6.3). Due to the three-dimensional nature of these friction ridge impressions, photography is best accomplished with oblique lighting (see Chapter 14). This method of side lighting utilizes light and shadow to bring out the details in the print.

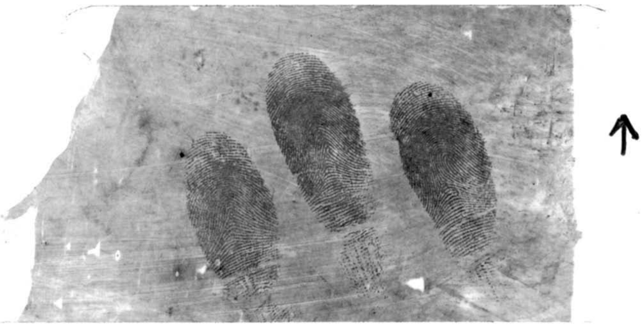
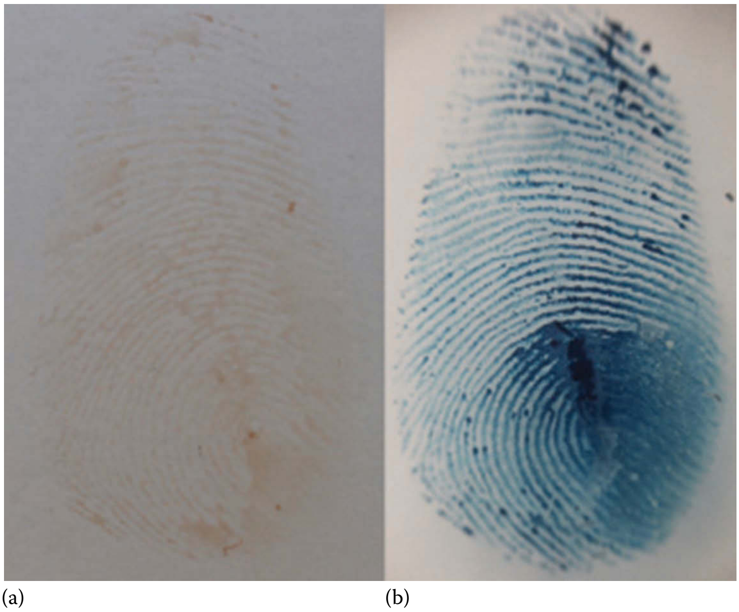


Figure 6.1 Fingerprints developed with fingerprint powder at a crime scene.



(a) (b)

Figure 6.2 A bloody fingerprint before (left) and after (right) processing with Amido black.

Regardless of whether the friction ridge impressions are latent, patent, or plastic, a *latent print examiner* (*LPE*) is responsible for analyzing the evidentiary print. The LPE is a forensic scientist who compares evidentiary prints with record prints to determine whether they may have originated from the same source. LPEs may also recover evidentiary fingerprints from crime scenes and/or from items of evidence in a laboratory. If the suspect is unknown, an LPE may choose to search the evidentiary friction ridge impression in the Automated Fingerprint Identification System (AFIS).

6.2 Matrix

Latent prints are left on a surface when friction ridges coated with a substance such as sweat or contaminants are deposited on a *substrate* or surface. This is analogous to an ink

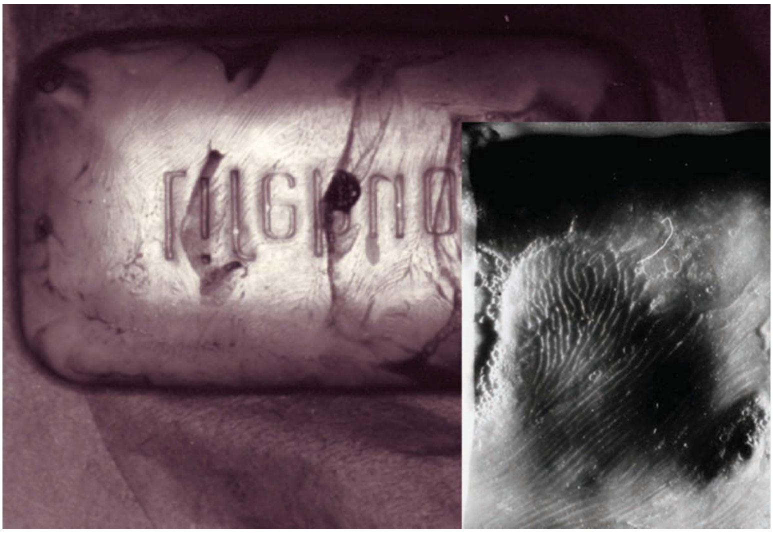


Figure 6.3 A patent print on a bar of soap identified to the suspect of a homicide.

pattern left by a rubber stamp. The rubber stamp is coated with ink, and the ink is pressed to a surface, thereby duplicating the stamp pattern. The substance coating friction ridges is made up mostly of sweat, but may also be any combination of lotion, grease, soap, or anything else an individual touched. These substances are known collectively as the fingerprint matrix.

The fingerprint matrix is predominantly composed of sweat. An average of 2–4 l of fluid is secreted per hour from the sweat pores of the body.[3] Most of this perspiration evaporates. Sweat is produced in coiled up glands in the skin (Figure 6.4). A gland is a "tubular shaped structure with a duct portion that coils in helical fashion down deep into the dermis layer."[3]

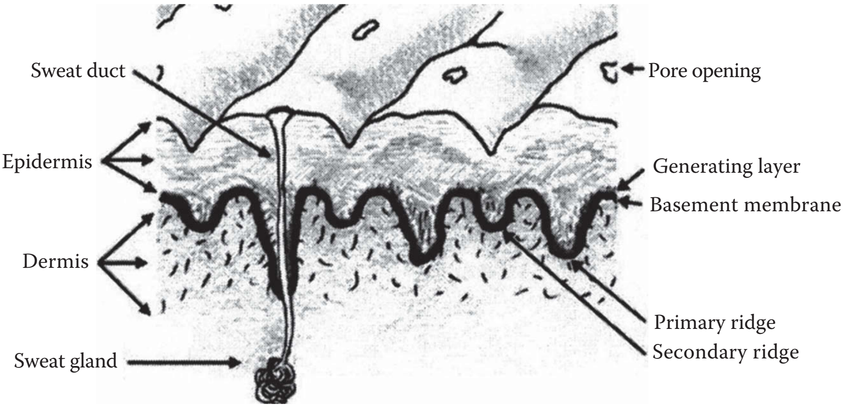


Figure 6.4 Cross section of the primary components of friction ridge skin, including the sweat gland, which conducts perspiration through the sweat duct to the pore opening on the friction ridge surface. (Reprinted with permission from Wertheim, K. and Maceo, A. 2002. The critical stage of friction ridge pattern formation, *J. Forensic Identif.* 52(1), p. 37.)

There are three types of sweat glands in the human body that produce three different types of sweat: apocrine, sebaceous, and eccrine. Each of these glands is produced in different parts of the body. *Apocrine* sweat is found in the genital and armpit regions. *Sebaceous* sweat is associated with regions of the body containing hair follicles, including the face and scalp. When the face or hair is touched, the friction ridges are coated with sebaceous sweat.

The glands associated with friction ridge skin, known as *eccrine* glands, form during embryological development. They develop between 8 and 32 weeks of fetal development.[3] Eccrine sweat is secreted from pores found along the friction ridges of the hands and feet. There are three to four million eccrine sweat glands in the human body.[4] An individual doing strenuous exercise in a warm environment may secrete up to 10 l of eccrine sweat.[4] Eccrine sweat is over 98% water. The remaining components are excretory products including the following organic and inorganic compounds: ammonia, magnesium, iodide, bromide, fluoride, cobalt, manganese, sulfur, mercury, phosphate, sulfate, iron, zinc, copper, lead, molybdenum, tin, urea, sodium lactate, proteins, lipids, cholesterol/fatty acids, and 22 amino acids.[3,5]

Sebaceous sweat, known as *sebum*, is secreted from pores associated with hair follicles. Sebum is composed of mostly lipids. De Paoli et al. identified more than 300 components of sebum in sebaceous fingerprints.[4] The lipid constituents include fatty acids, wax esters, squalene, and cholesterol.[5] Latent fingerprints often contain a mixture of eccrine and sebaceous sweat, but they also include other contaminants from surfaces touched during the day. Contaminants may include lotion, cosmetics, soap, or grease.

The composition of friction ridge impressions is especially important when determining which chemical reagent to use in order to visualize the latent prints. Most latent print reagents react with amino acids or lipids.[6] Regardless of the development method used, latent prints must be visualized to compare them with exemplars.

6.3 Substrate

The *substrate* is the surface the latent print is deposited on. Substrates vary in porosity, texture, and contour. A substrate may be smooth or rough, flat or curved, porous or nonporous. Porous surfaces are absorbent, which means that they are permeable to gases or liquids. Examples of porous surfaces include paper, cardboard, and unfinished woods. If water is poured onto these surfaces, they will absorb some of that water. Nonporous items are nonabsorbent. Examples of nonporous surfaces include glass, plastic, or metal. If water is poured on these surfaces, it will run off and none will be absorbed.

Rough or highly textured surfaces are not ideal for latent print recovery. When a latent fingerprint is deposited on a rough surface, such as the grip of a gun or a window screen, the minutiae are not recorded in detail. The pattern is interrupted by the texture of the surface. It may be more beneficial in these cases to swab the surface for touch DNA (see Section 6.5).

When friction ridges come into contact with a nonporous item, a print may be deposited on the surface. It will stay on the surface unless it is wiped off or obliterated by environmental or physical forces. Latent prints on nonporous surfaces are therefore fairly fragile. Chemical reagents and fingerprint powders are used to develop fingerprints on nonporous substrates. Since latent prints are mostly composed of sweat, they are readily

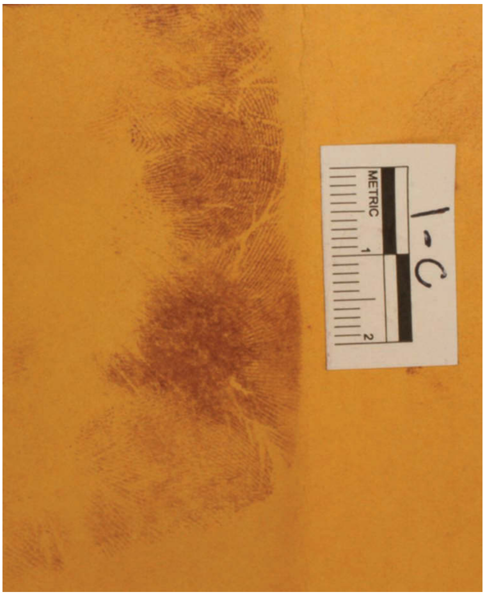


Figure 6.5 A latent print on a manila envelope developed with ninhydrin.

absorbed into porous substrates. Therefore, they are more stable than latent prints deposited on nonporous items. These prints are developed using chemical reagents that permeate the porous substrate (Figure 6.5).

6.4 Distortion

Skin is an elastic, three-dimensional surface. Each time a finger is pressed onto a substrate, the resulting two-dimensional latent print therefore appears slightly different. The substrate, matrix, deposition pressure, and movement of the subject can all result in distortion in the latent print. *Distortion* can change the appearance of the fingerprint so it appears deformed in comparison with the natural position of features on the original finger. Distorted latent prints can appear smeared, stretched, or twisted.

Through the normal handling of objects, the movement of the friction skin coupled with its elasticity results in various types of distortion. The pressure and movement applied while the print is deposited result in the following types of distortion: compression, lateral or directional (vertical, horizontal, or twisting), or deposition (downward) pressure (Figure 6.6). The forces applied when a latent print is deposited on a substrate can cause slight differences in the appearance of a latent print. Some of these differences include variable spacing between ridges, the width of ridges, the appearance of minutiae points, and the distances between minutiae points.[7]

The substrate can also cause the latent print to appear distorted. The latent print will appear different on a curved surface versus one that is flat, a soft surface versus one that is hard, or a textured surface versus one that is smooth. Similarly, the matrix of the fingerprint affects its appearance. Wet friction ridges appear distorted in comparison with those coated with an average amount of eccrine deposits.

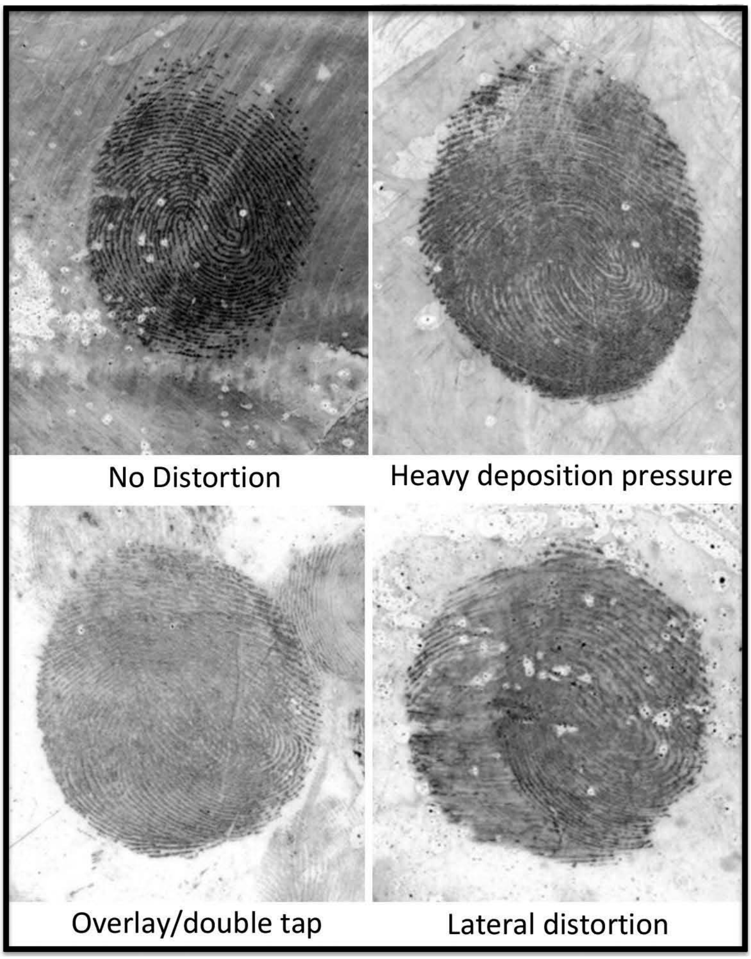


Figure 6.6 The same thumb impression, developed with fingerprint powder on the same surface, demonstrating several common types of latent print distortion. The top left print has no visible distortion. The top right print shows distortion from heavy deposition pressure. The bottom left print was placed on the surface twice, causing an overlapping friction ridge impression often referred to as an overlay or "double tap." The bottom right print shows horizontal lateral distortion.

The method of latent print development can also influence the appearance of a latent print and cause distortion. Fingerprint powder development often results in "brush marks" in the latent print. It can also cause granules of fingerprint powder to build up between friction ridges, distorting the appearance of minutiae and other identifying features.[8] The distortion seen in many latent prints developed with ninhydrin appears similar to the distortion seen in wet latent prints, due to the aqueous nature of the reagent, which often diffuses the friction ridges.

Distortion is not usually an issue when dealing with exemplar prints. The fingerprints on a tenprint card will appear consistent due to the nearly uniform force applied to each finger during the recording process. However, there will be circumstances in which the exemplar print appears distorted and may have to be re-rolled. Regardless of the distortion observed in the latent and exemplar prints, the minutiae will be located in the same relative positions along the friction ridges in a latent or exemplar print.

6.5 Aging Latent Prints

In some investigations, it may be beneficial to know how long a latent print has been on a surface. For example, a latent print recovered from the interior of a stolen vehicle is identified to a suspect. The suspect insists he did not steal the car. Instead, he asserts he test-drove that exact car a year prior. How can we test his assertion? Is it possible to "age" fingerprints or determine how long they have persisted on a surface? As of the publication date of this text, there is no scientific method for directly dating latent print residues.

It is possible to date a latent print indirectly because of the circumstances in which it is deposited. For example, a patent print left in blood must have been made while the source of the blood was still wet after the wound was made. Thinly deposited blood will dry within minutes. This can be demonstrated in a laboratory. In another example, a small piece of broken glass at a crime scene is found to have the suspect's thumb impression on one side and index finger on the opposite side. The only way that could happen is if the suspect picked up the fragment after the glass was broken (see Chapter 15).

There are many factors that contribute to how long a latent print will persist on a surface, including the chemical composition of the latent print, the nature and condition of the substrate, the development technique used, and the environment.[9–18] Immediately after a latent fingerprint is placed on a surface, it begins to change. The chemical compounds in sweat degrade. There are hundreds of chemical compounds present in eccrine and sebaceous excretory deposits. The components and ratios of these compounds are unique to the individual and are based on many different factors, including diet, age, sex, race, medication, health, metabolism, occupation, and stress.[9–18] Deposition methods such as the time the friction ridges were in contact with the substrate, the angle of contact, and the pressure placed on the substrate also affect how long a print may persist on a substrate.[10] The environmental factors that affect latent print persistence include temperature, humidity, exposure to sunlight, and weather. Surfaces may also have an impact on the persistence of latent prints. Some of these variables include surface texture, cleanliness, shape, porosity, and temperature.[10] Research projects have focused on finding a stable component of latent print residue and determining how the optical, electrostatic, and chemical properties change over time.[3,11,14–18] Some of those components identified are saturated fatty acids and wax esters.[3,11,14–18] Frick et al. also noted significant inter-donor variation.[11] The same study observed rapid changes in lipid composition over 28 days, and that squalene in particular diminished rapidly, a process that was accelerated when latent prints were exposed to light.[11] Cadd et al. describe another study conducted by Popov et al., which examined how the topography of a latent print changes over time.[10] They observed and measured how an aging print changed in height, width, and total area.[10] They found that the exothermic process of the breakdown of fatty acids caused the friction ridges to spread, though there was no change in height over time.[10] Similar research has been done by Dorakumbura et al.[13]

Research continues in the area of aging latent prints. A challenge researchers face is the number of variables involved in this process, only some of which are listed above. However, new technologies with better sensitivity may allow researchers to control for most of the aforementioned variables and find a nondestructive method of aging latent prints on substrates.

6.6 Touch DNA

Similar to latent prints, DNA profiles recovered from crime scenes and evidentiary items can be compared with DNA exemplars in order to determine whether they may originate from the same source. Advances in DNA analysis have made it possible to obtain DNA evidence from skin cells. Consequently, items that have been touched, regardless of the substrate they are deposited on, can be used for DNA collection. Whether the substrate is rough or smooth, porous or nonporous, latent prints can be sampled for DNA. This type of DNA is known as *touch DNA*.[19–21]

DNA is an acronym for deoxyribonucleic acid. DNA is found in every cell of every living organism. There are two types of DNA found in human cells: nuclear DNA and mitochondrial DNA. Nuclear DNA is found in the nucleus of the cell. Mitochondrial DNA is found in the mitochondria of the cell, outside the nucleus (Figure 6.7). Forensic biologists analyze nuclear DNA from touched evidence to create a DNA profile that can either be compared with suspect DNA or searched in the DNA database known as the Combined DNA Index System (CODIS).

Since the 1980s, samples of biological evidence from crime scenes have been analyzed for DNA. Initially, biological material only yielded a DNA profile if the sample size was 250 ng or more.[20] Samples must be large enough to be visible to the human eye. Over time, the technology and sensitivity of DNA analysis have improved, allowing for the collection of smaller samples from crime scenes and evidentiary items. Biological evidence no longer needs to be visible to utilize it for DNA analysis.

When an individual touches a surface, skin cells are shed and may adhere to the surface. Humans shed tens of thousands of skin cells daily.[19] Skin cells are invisible to the naked eye. A sample with a mass of less than 100 pg can yield a DNA profile (1 pg is one trillionth of a gram).[20] Extensive research has shown that touch DNA can successfully be recovered from latent prints on various surfaces as well as from weapons, vehicles, clothing, wood, fabric, glass, briefcase handles, pens, car keys, locker handles, telephone

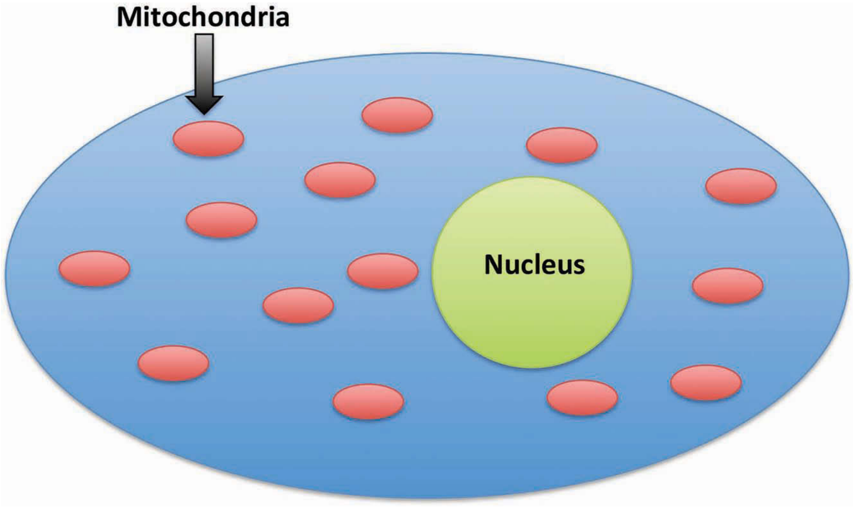


Figure 6.7 A schematic of a cell with a nucleus surrounded by mitochondria. Nuclear DNA is found in the nucleus of the cell, while mitochondrial DNA is found in the mitochondria of the cell.

handsets, doorbells, chocolate bars, electrical cords, knife handles, glass, gloves, paper, and other items.[19–24]

Touched surfaces that are rough in texture or otherwise unsuited to preserving friction ridge patterns are excellent sample areas for collecting touch DNA evidence. Examples of unsuitable surfaces include textured gun and knife grips, clothing, and rough, unfinished wood. These areas can be sampled for DNA analysis in the following ways: swabbed with a wet sterile swab, lifted with adhesive tape, or scraped with a sterile razor blade (Figure 6.8).[19] However, one does not have to choose whether to collect latent prints or DNA from a surface. With the increased sensitivity of DNA, fingerprint examiners have the option of first processing latent prints with chemicals or powders, then swabbing latent prints that have no value for identification.

Any unusable, smudged, or poor quality prints may be sampled for DNA. After lifting latent prints from a surface, that surface can be swabbed for skin cells. Latent prints can also be swabbed directly following certain development processes, but only after that friction ridge impression has been documented thoroughly. For example, superglue® fuming results in encapsulated prints that can be swabbed with acetone or methanol. However, some latent print development techniques damage DNA or reduce the DNA yield. These techniques include superglue® fuming, indanedione (6 days or more following treatment), short wave ultraviolet light (~254 nm), vacuum metal deposition, silver nitrate, and physical developer.

Because touch DNA requires so few cells to be viable, it is particularly subject to contamination. Potential sources of contamination include fingerprint brushes, forceps, scissors, or gloves.[25–28] Even the act of breathing on an item can result in DNA transference. Where it appears that DNA analysis will be requested, fingerprint examiners and crime scene technicians must take great care to change gloves frequently, wear particulate masks to cover the mouth, and limit handling of evidentiary items.

Even the act of processing a crime scene for latent prints using a standard fiberglass fingerprint brush and fingerprint powder may contaminate the scene.[28] Secondary and tertiary transfer of DNA has been recorded with contaminated fingerprint brushes and gloves.[29,30]

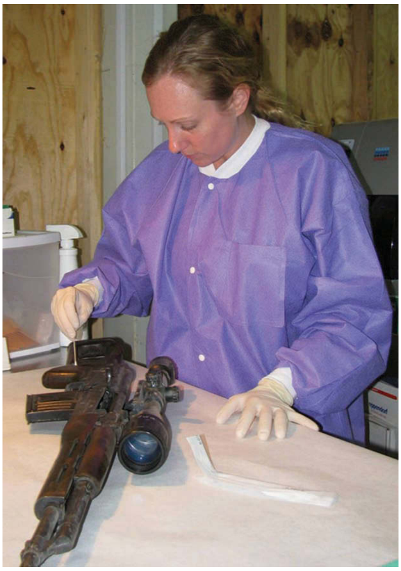


Figure 6.8 A forensic scientist swabs the grip of a weapon to obtain a sample for DNA analysis.

Szkuta et al. found that some fingerprint brushes are contaminated right out of the package.[28] Brushes can be cleaned with 1% hypochlorite or 5% Virkon.[28] Disposable powder packets and fingerprint brushes are used to avoid contamination.[25,28]

DNA analysis is a powerful tool that has become more effective and prevalent in recent years. The analysis of touch DNA is becoming common practice in the United States. However, DNA contamination in the forensic sciences "has the potential to change the outcome of a criminal investigation and may have significant social and financial repercussions."[25] Forensic scientists must keep in mind the dangers of contamination and remember to analyze all evidence in context. The "Phantom of Helibronn" case is a reminder to take all evidence in context and keep in mind the sensitivity of DNA analysis.[31] This case involved a 16-year hunt for an alleged serial killer that spanned several European countries.[31] "Matching" female DNA profiles were recovered from various homicides, burglaries, robberies, and even in the death of a police officer.[31] Detectives hypothesized that a serial killer was to blame. In reality, the DNA profile was the result of contamination from a woman who worked at the factory that manufactured the swabs used to collect DNA from all of those crime scenes.[31] Countless financial resources and man-hours were wasted in the hunt for a serial killer, when in reality the evidence was simply a case of contamination. As this case demonstrates, the ability to analyze touch DNA is a powerful forensic tool, but must be used with caution. While touch DNA is not currently used regularly for all investigations worldwide, it will be used more frequently in the future due to technological and scientific advancements in the field.

6.7 I Had a Case: Aging Latent Prints

[Submitted by Ken Moses, Forensic Identification Services (retired, San Francisco Police Department)]

Burglars in San Francisco broke into the Harley Davidson Motorcycle shop late on a Sunday night. Entry was gained by sawing through the sheetrock wall of an adjacent shop. The safe in the office was forcibly entered with chisels and sledgehammers that were then left at the scene. Due to all the dirty and greasy surfaces, the only latent print found by investigators was on a compartment door inside the safe. When dusted with powder, this print looked dark and "fresh" and lifted off easily with tape.

The next day, the print from the safe was searched in AFIS and identified to the right thumb of a suspect. When investigators contacted the Harley Davidson store to ask them if they know this suspect, the owner stated, "Yes, he used to work here but he died 6 years ago." The death was confirmed. His fingerprints had not been purged from the system.

The lesson learned is that it is most often impossible to state when a particular latent print was deposited on a surface, even though it may look "fresh."

6.8 Chapter Summary

There are three types of evidentiary friction ridge impressions found at crime scenes and on items of evidence: latent, patent, and plastic prints. Latent prints are invisible impressions formed when a matrix deposits a friction ridge pattern on a substrate. The matrix of a latent print is composed of eccrine sweat from the friction ridge pores, sebaceous sweat from touching other parts of the body, and/or contaminants from the environment. Latent prints must be developed with powders, powder suspensions, or chemical reagents to make them visible. Patent prints are visible to the naked eye. The matrix is a visible material such as blood or paint. Plastic prints are impressions in soft materials such as clay, thick paint, or wax. It is not possible to determine how long a friction ridge impression has been on a surface. Touch DNA is a powerful forensic tool, but contamination and context are concerns due to the sensitivity of the technique and investigative value.

6.9 Review Questions

1. What is a latent print?
2. How is a patent print different from a plastic print? Give an example of each.
3. What are the duties of a LPE?
4. What is eccrine sweat composed of?
5. Is it possible to determine how long a latent fingerprint has been present on a surface? Why, or why not?
6. What is touch DNA?
7. What is the Combined DNA Index System (CODIS)?
8. How is touch DNA collected from an item?
9. What are possible sources of DNA contamination?
10. How can the LPE avoid DNA contamination when searching for, processing, collecting, and analyzing fingerprint evidence?

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Biometrics
Livescan and AFIS

7

> Names can be fraudulently changed; faces can be altered, identities hidden, histories covered. Fingerprints, however, do not change. Fingerprints link a person to a history, even if the history states that there is no history.
>
> **Peter Komarinski**[1]

LEARNING OBJECTIVES

- Define "biometrics" and give examples of modern applications of biometrics.
- Describe how computers have revolutionized the forensic sciences.
- Explain why it is important to take high quality, comprehensive exemplar fingerprints.
- Describe AFIS and explain how it was developed.
- Explain the role of the tenprint examiner and the latent print examiner.
- Describe how latent prints are searched in AFIS.

7.1 Biometrics

Criminal identification has come a long way since the days of Bertillonage. Anthropometry was the first method of criminal identification using biological measurements. Fingerprints replaced anthropometry as more reliable means of individualization. Fingerprints are an example of a biometric. *Biometrics* (from the root words "bio" meaning life and "metric" meaning measure) refers to using unique biological measurements or features to identify individuals.

Computers have not only made fingerprint acquisition, comparison, and storage more efficient and effective but have also expanded the field of biometrics to a wide array of biological measurements beyond fingerprints. There are many examples of forensic biometrics, including handwriting analysis, odontology (examining the unique features of teeth), anthropology, and DNA. Examples of modern digital biometrics include the following: iris pattern identification, retinal vasculature identification, facial recognition, voiceprint identification, gait pattern identification, hand geometry measurement, keystroke dynamics (the method and cadence of typing), and hand vasculature identification.[2–6] Iris scans capture the unique patterns in the pigmented section of the eye (Figure 7.1). Retinal scans detect the vascular patterns in the interior rear surface of the eye. Facial recognition software analyzes the contours of the face. Voiceprint identification captures the unique patterns of speech. Gait pattern analysis captures the unique patterns in the way we walk. Hand geometry captures the unique shapes of our hands and hand vasculature biometrics measures the pattern of veins and capillaries in the hand.

Biometric analysis is not limited to the forensic sciences. Fingerprint scanners on mobile phones are now commonplace methods for securing data on the phone. Walt Disney

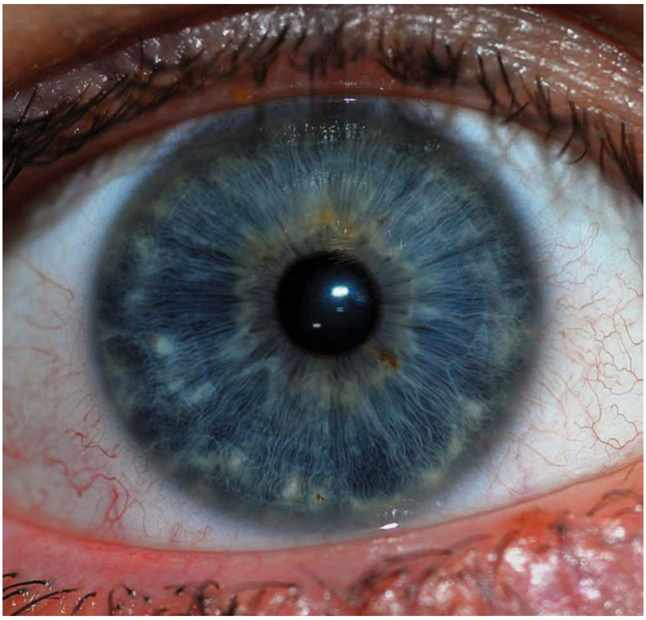

Figure 7.1 The iris, or colored portion, of the eye contains unique patterns that can be used for identification, similar to a fingerprint.

World in Orlando, Florida, requires its pass holders to scan their fingerprints to prove their identity upon entry to the park (Figure 7.2). All foreign visitors entering the United Arab Emirates at Abu Dhabi airport are subjected to iris scans to ensure that previously expelled individuals or individuals on a watch list or wanted list do not enter the country illegally.

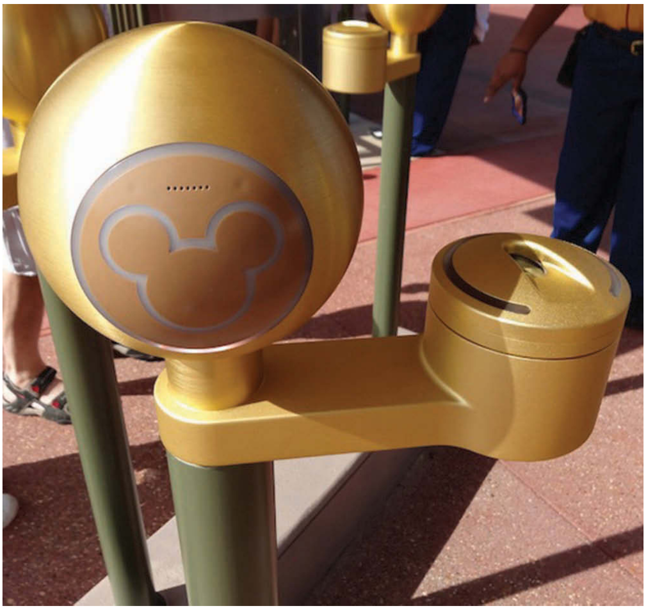

Figure 7.2 Biometric fingerprint scanners at Walt Disney World in Orlando, Florida.

Schools and retailers are testing the possibility of using fingerprint scanners to pay for food and other items. Biometrics can be used to combat illegal activities such as fraud, forgery, and identity theft. Biometrics is the future of secure, efficient, and convenient access to all types of services we use in our daily lives.

Fingerprints are still the most common biometric used for criminal identification around the world. Fingerprints were the first biometric to be digitized for analysis by a computer. The computer system that stores the fingerprint databases and searches for matches both to known and to unknown fingerprints is known as the *Automated Fingerprint Identification System* (*AFIS*). AFIS is used not only to identify criminals but also to perform criminal background checks on job applicants, teachers, taxi drivers, etc.[1] There are two main purposes of AFIS as a law enforcement tool. One purpose is to determine if an individual has been arrested before, regardless of the name or history the arrestee provides. The other purpose is to search for matches to latent prints collected from crime scenes.

7.2 Livescan

In order for the AFIS to perform its duties, the exemplars must first be captured and converted to a language the computer can read. If an inked tenprint card is available, that card can be scanned into the AFIS computer on a flatbed scanner. As mentioned in Chapter 5, a livescan device can also be used to capture the necessary fingerprint images digitally. The livescan is similar to a document scanner in that it creates a digitized replica of the friction ridge detail. The resulting print will appear on the screen in black and white. It looks like a tenprint card, with black ridges on a white background (Figure 7.3). The fingerprints are taken using the same process for inked tenprint cards. Each finger is rolled, starting with the number one finger, from nail to nail. Then the flats and thumbs are recorded.

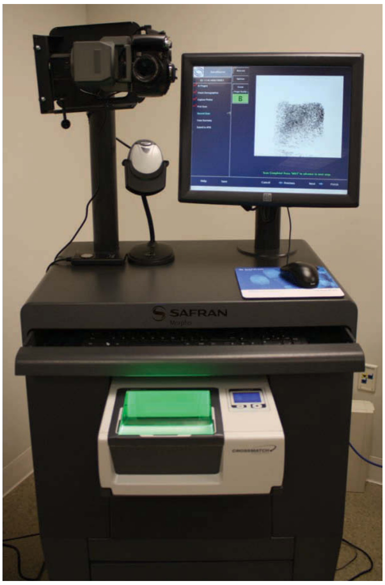

Figure 7.3 A fingerprint scanned at a livescan terminal appears on the screen of the computer monitor.

Many law enforcement agencies have livescan terminals. These consist of a scanner for recording fingerprint images, a computer monitor to view the images, and a keyboard for recording demographic and criminal information. There are a multitude of vendors who build and maintain different types of livescan terminals. While they look different, they have similar functionality.

The image must be recorded at a high enough resolution to result in a high quality reproduction. Taking a comprehensive record of the known fingerprints, either with ink or via a livescan, is a crucial step for successfully utilizing AFIS technology. If the initial image acquisition is poor—if the prints are not rolled nail to nail, if the hands are transposed, or if the quality of the images is poor—then a latent print may never be identified to the corresponding suspect's record prints. The latent may be any portion of friction ridge skin from any part of the finger, finger joint, or palm.

There are several advantages to using livescan as a record print capture method. The records are stored electronically, so there is no longer a need for warehouses full of filing cabinets for storing tenprint cards (Figure 7.4). The process is also faster than inking individual tenprint cards since no medium is necessary to record the friction ridges. The lack of ink also makes it a cleaner process. The fingerprints are immediately shared with other agencies and departments. City, county, state, and federal agencies receive copies of the fingerprint record electronically. It is no longer necessary to create several copies of a tenprint card to mail off to other agencies. There is some quality control in that the computer can reject prints that are not adequate, though no computer can replace human decision making in this regard.

As with most technology, the quality and efficiency of these livescan devices have improved over the years and will continue to improve. Computers have historically become better, faster, more portable, and cheaper with time. This is true for personal computers, which were at one time prohibitively expensive. Many people now carry smart phones—computers in their pockets. Similarly, livescan technology has become increasingly available to law enforcement agencies that may not have been able to afford the technology in the recent past.

Figure 7.4 Filing cabinets for tenprint cards.

7.3 History of AFIS

The current, efficient use of friction ridge detail as a biometric is only possible due to the advent of the silicone microchip, and consequently the computer, in the early 1970s.[1,7] A computer is a device that can be programmed to carry out complex arithmetic equations or logical sequences much faster than a human can and with greater accuracy. It can also perform multiple functions at the same time. The computer therefore showed great promise for solving the problem of the overwhelming volume of tenprint cards that required humans to classify, file, and search by hand.

Law enforcement agencies' identification bureaus historically employed fingerprint examiners who were responsible for classifying, filing, and searching for tenprint cards by hand. The FBI's identification bureau, known as the Identification Division, was established in 1924 "to provide a central repository of criminal identification data for law enforcement agencies. The original collection of fingerprint records contained 810,188 records."[7] The technicians employed in the Identification Division were responsible for classifying, filing, and searching approximately 30,000 tenprint cards submitted by law enforcement agencies around the country every day.[7] The manpower necessary to sustain this ever-expanding repository would soon reach critical mass.

The AFIS computer was developed to address this problem. A computer can store an abundance of information in a small space. It can perform simultaneous functions, unlike a human who must perform one task at a time. A computer can work quickly and efficiently 24 h per day, 7 days per week, 365 days per year. As of 2012, the FBI's criminal fingerprint database known as *Next Generation Identification (NGI)*, formerly known as the *Integrated Automated Fingerprint Identification System (iAFIS)*, contained more than 70 million criminal files: over 700 million individual fingerprints. The database grows larger every day. Identification bureaus would have had to employ tens of thousands of individuals to keep up with the volume of work.

The United States, France, Canada, the United Kingdom, and Japan all developed computer systems to address the needs of overwhelmed and unsustainable identification bureaus.[1,7] The Royal Canadian Mounted Police put an automated system in place in 1977.[1] The city of San Francisco, California was the first jurisdiction to use the AFIS on a routine basis in the United States (Figure 7.5).

When the citizens of San Francisco were asked whether they wanted a fingerprint computer, they approved the ballot proposition with an 80% majority.[7] An AFIS system was installed in 1983 and a new unit, called Crime Scene Investigations, was formed.[7] Crime scene investigators were trained in the use of the system and searched their own cases when they recovered fingerprints from crime scenes. Over the next 2 years, the "San Francisco experiment" resulted in a dramatic increase in fingerprint identifications.[7] Ten times as many fingerprints found at crime scenes were identified to suspects over 2 years.[7] The burglary rate decreased by 26% over the next 4 years.[7]

The experiment was a great success that resulted in the proliferation of AFIS systems in law enforcement agencies throughout the United States and around the world. In 1992, iAFIS imported 32 million fingerprint cards into its database. In 1997, the United Kingdom installed its own national AFIS database. Over forty years after the advent of AFIS, most law enforcement agencies use the system routinely.

SAN FRANCISCO
POLICE
CRIME SCENE INVESTIGATIONS UNIT

Figure 7.5 A San Francisco Police Department Crime Scene Investigations Unit patch.

7.4 Record Searches

One of the main functions of AFIS is to store, classify, and search arrest records. When an individual is arrested, the arrestee's prints are taken either in ink on a tenprint card or with a livescan machine. The palm impressions may also be recorded at this time. Demographic and other identifying information are recorded. Descriptions of other individualizing marks such as scars, marks, and tattoos may also be recorded and/or photographed. The fingerprints will then be classified, or coded, by the computer and searched in the database. If the computer locates a candidate file with matching fingerprints, a *tenprint examiner* will confirm the match. A tenprint examiner is an individual whose job is to search and confirm arrest records using the AFIS computer.

One of the most important aspects of this function is the *coding* of the fingerprint by the computer or tenprint examiner. The fingerprint is coded when the computer picks out the minutiae in the fingerprint. This is known as *feature extraction*. The AFIS computer is programmed with an algorithm that recognizes minutiae. It can also recognize the direction of ridge flow, the distance between ridges, and the number of intervening ridges between minutiae.

After a friction ridge impression is coded, the computer searches the database for similar arrangements of minutiae. It then returns *candidates,* or a list of possible matches, who have similar features in similar positions. The tenprint examiner can then determine which of the candidates is a likely match to the arrestee. There can be 100 or more minutiae in a rolled fingerprint. In a latent print, however, there are far fewer minutiae since it is deposited unintentionally on a variety of substrates.

7.5 Latent Print Searches

The second major function of AFIS is to enter, code, and search evidentiary latent prints against the tenprint database (as well as the unsolved latent [UL] database). A latent print, unlike a rolled fingerprint, is deposited unintentionally. The print may be of poor quality, ambiguous origin, or distorted. It may have been left on a curved or rough surface. It may be the side of a palm or a fingertip. If a good enough quality evidentiary print is recovered from a crime scene, but there is no suspect to compare it to, it can be searched in the AFIS database. It is up to the latent print examiner to determine whether it is appropriate to search a given print in AFIS.

In order to search an evidentiary print against the AFIS tenprint database, the database of all record prints in a given jurisdiction, the latent print must first be digitized and entered into the computer. The print can be either scanned on a document scanner or photographed. The scanned or photographed latent print will then appear on the computer screen. The latent print examiner will enter the case number, agency, and any other data pertaining to the case at hand. The latent print examiner can also instruct the computer which finger or hand to search, if known, and what fingerprint pattern type to search for, if the pattern type can be discerned.

Once the case data is entered, the latent print examiner rotates the print so it is in the proper upright orientation. In some systems, the core and delta(s) are selected. Next, the latent print examiner and/or computer codes the minutiae. If the computer codes the print, the latent print examiner may deselect questionable or inaccurate minutiae points, or add points the computer may have missed (Figure 7.6).

When the latent print examiner is satisfied with the latent print coding step, the search is launched. The computer then returns a list of candidates, similar to the tenprint search discussed above. A candidate in this case is an individual whose exemplar print is recognized by the computer as having a similar arrangement of minutiae as the latent print. The

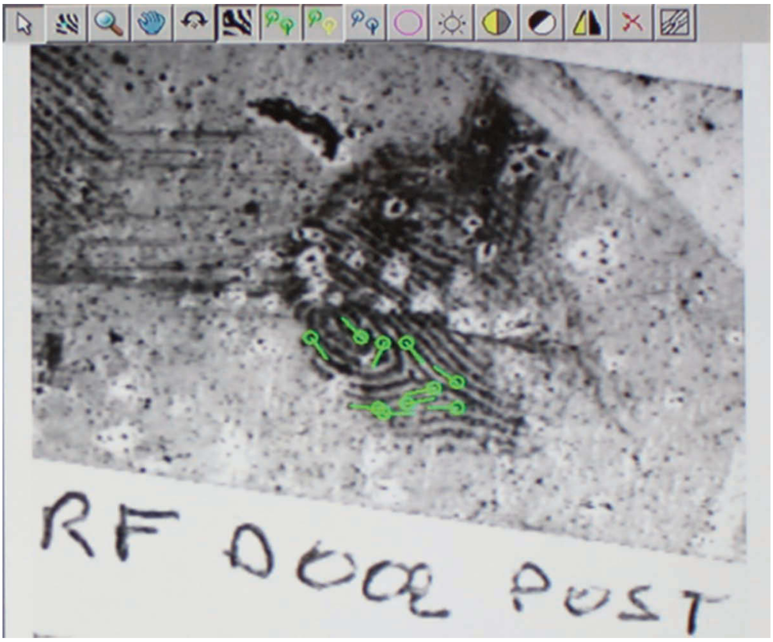

Figure 7.6 This latent lift card was scanned into AFIS. The minutiae (green circles) were selected by the latent print examiner. The green lines indicate the directionality of the minutiae.

latent print examiner then compares the latent print to the known prints of each candidate. If a likely match is found, it is documented, and another latent print examiner verifies the identification (Figure 7.7). It is important to know that the latent print examiner, not the computer, decides whether an AFIS record matches an unknown print from a crime scene.

If the latent print does not match any records in the AFIS database, the latent print examiner can then choose to search it against the *UL database*. This database stores all unidentified latent prints entered into the database. While this may not result in identification to a suspect, it may lead to contextual investigative information by linking several crime scenes or evidentiary items. If the latent print does not match another unidentified latent print, it can be saved, along with the accompanying case data, into the UL database for future searches. Every new tenprint card entered into AFIS is searched against the UL database. If the computer detects a possible match, the case is forwarded to a latent print examiner who will verify the identification.

An increase in tenprint records entered into AFIS will not necessarily increase the probability of a fingerprint match. With AFIS, the quality of the tenprint records is more important than the quantity of records in the system. If a latent fingerprint is the left side

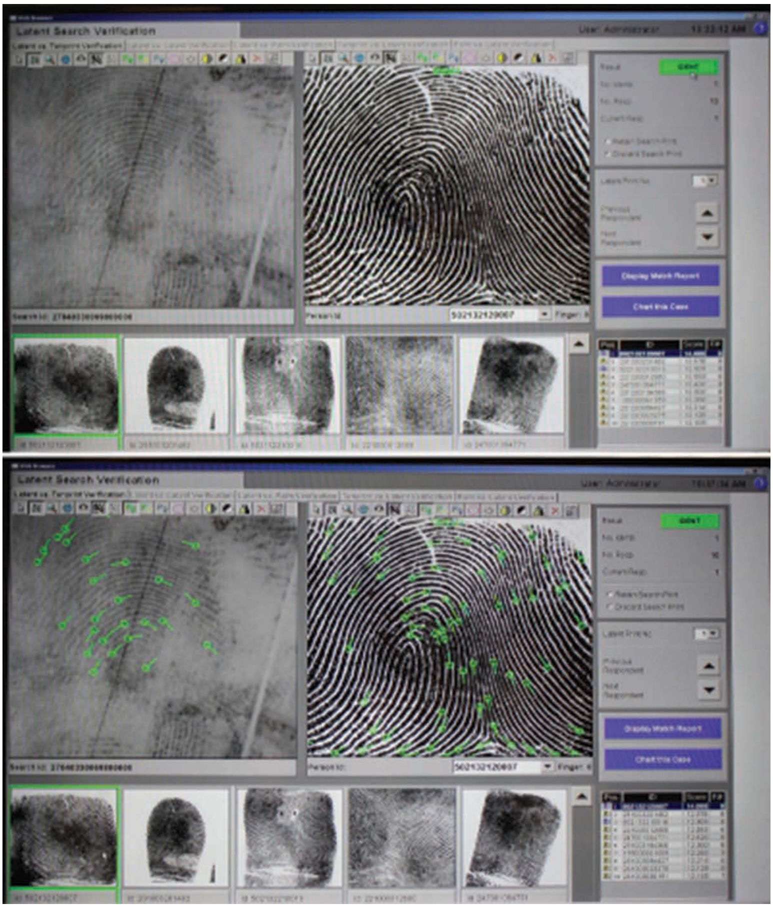

Figure 7.7 This latent lift was scanned into AFIS and identified to a suspect. The identification is shown with (bottom) and without (top) minutiae selected.

and left delta of the right thumb, but the thumbprint on the tenprint card was not recorded "nail to nail," that latent fingerprint may never be identified and the case may never be solved. This is why it is so important to record quality, comprehensive known fingerprints.

7.6 Future of AFIS

As we increasingly rely on computing in our daily lives, we must remember that the technology is only as good as the people who build the systems, write the algorithms, run the machines, and conduct the analyses of the data. As with all computers, the future of AFIS is smaller, faster, and more accurate systems (Figure 7.8). Coding algorithms have consistently improved over time, resulting in improved minutiae selection by the computer. Modern AFIS systems have been shown to correctly source a latent print with six minutia points 86% of the time for fingerprints and 61% of the time for palm prints.[8]

The problem with this increase in both database size and efficiency is that as the algorithms improve, there may be a corresponding increase in erroneous identifications due to the return of candidates that are close nonmatches. Latent print examiners must take great care not to become biased by, or put too much confidence in, an AFIS "hit." This concern has been addressed in several recent scientific publications.[9,10]

AFIS interoperability refers to the ability of one AFIS computer to communicate with another AFIS computer that may be in a different jurisdiction and built by a different company. In the early days of AFIS, computers built by different companies were not able to communicate. Therefore, if a latent print was entered into one system and the corresponding record print was located in a different system, the latent print examiner would not be able to identify that latent. Thanks to increased awareness of the need for AFIS

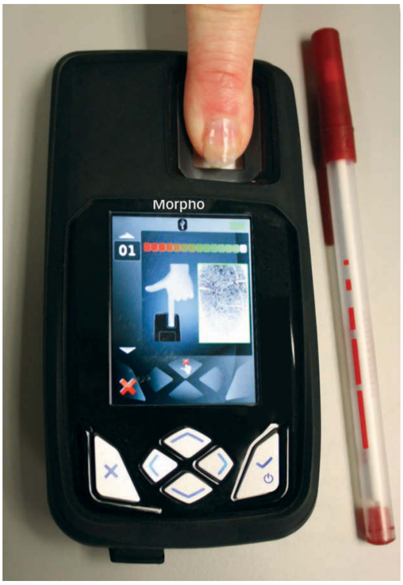

Figure 7.8 A mobile ID unit.

interoperability, and public policy, these systems are increasingly able to share information, thereby increasing their efficacy and efficiency.

It is certain that as the population of the world increases, so will the number of arrests. AFIS systems are keeping up with this trend with faster turnaround times for searches and larger database capacities. One way to increase the effectiveness and accuracy of AFIS is to provide extensive training and retraining to anyone who uses AFIS: latent print examiners, law enforcement officers, tenprint examiners, etc. This will ensure that the images captured are of the highest quality and that the input of data is thorough and consistent.

It will also be necessary to streamline the AFIS search process. As automated encoding improves, it becomes unnecessary to encode prints manually, unless there is background interference in the image.[11] It is also not necessary to search an entire candidate list, as most matches are found in the top five candidates.[11] The United States Federal Bureau of Investigation (FBI) found that 95% of hits in its NGI system were in the top three candidates.[11] As the technology improves, it is critical that we remain judicious and aware of potential bias arising from our close working relationship with technology.

7.7 I Had a Case: AFIS Interoperability

In 2003, there were a string of forcible rapes in several cities in California's east bay region, just east of San Francisco, California. The modus operandi (MO) in each of these cases was similar. The offender would enter a family owned restaurant from the back door after the restaurant had closed for the night. He would then sexually assault a woman working alone in the kitchen area. Each of these rapes was located in close proximity to a Bay Area Rapid Transit (BART) system station. This transit system has 500 linear miles of track and 46 stations.[12]

At one of these crime scenes, in the city of Hayward, California, a latent print was developed. The latent consisted of close to an entire hand, complete with several fingers, finger joints, and a palm. The latent was searched in the Hayward Police Department's AFIS system with no success. Over the next several months, the author made arrangements to drive to several major cities in the area to search other city and county AFIS systems. Finally, a search of the city of San Francisco's database proved fruitful. The search resulted in a fingerprint hit, a suspect was developed, and the new investigative lead resulted in the capture of a serial rapist. By the time the rapist was arrested, several other women had been raped. Had the AFIS systems been able to communicate and share information at that time, those women would not have become victims.

7.8 Chapter Summary

Biometrics refers to using unique biological measurements or features for personal identification. Digital records can be recorded, codified, and searched by computers. The most frequently utilized biometric in the criminal justice system is the friction ridge impression. Record print captured via a livescan device or with ink must be comprehensive and of good quality. If the initial record acquisition is poor, a latent print may never be identified to corresponding record prints. AFIS was developed to digitally analyze, store, and search for prints. Its two main functions are to store, classify, and search tenprint records from arrests and to enter, code, and search latent fingerprints against the tenprint database and UL database. Both functions require dedicated, trained personnel, and are not performed by the computer alone.

7.9 Review Questions

1. What is biometrics?
2. What are some examples of forensic biometrics?
3. What is a livescan terminal, and what is its use in the criminal justice system?
4. Why is it important to take high-quality, comprehensive record prints?
5. What is AFIS?
6. What invention of the twentieth century made AFIS possible?
7. What are the two main functions of AFIS?
8. How are latent prints searched in the AFIS system?
9. What are some concerns with the increasing database sizes and improving algorithms?
10. What are some ways AFIS searches can be made more efficient?

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Latent Print Development

II

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Introduction to Processing Methods

8

LEARNING OBJECTIVES

- Understand how fingerprint residues react with porous, nonporous, and semi-porous substrates.
- Explain physical and chemical processing methods.
- Describe health and safety concerns and how to avoid exposure.
- Understand how to handle evidence properly.
- Understand how fingerprint reagents affect DNA processing.

8.1 Matrices and Substrates

Because latent fingerprints are invisible, they must be processed, or developed, to make them visible. Once they are visualized, they are documented and analyzed. There are four major limitations that affect the quality of prints recovered from the crime scene or items of evidence:

- Condition of the substrate (texture and permeability)
- Environmental effects (dry, humid, rain, wind, etc.)
- Quantity of latent print material deposited
- Method(s) of development, documentation, and collection

Recall that latent fingerprint deposits are composed of 98% water, lipids (fatty acids, cholesterol, squalene, and triglycerides), amino acids and proteins, environmental contaminants (lotions, soaps, cosmetics, etc.), and the products of environmental chemical reactions following deposition.[1–4] The majority of these components are metabolic excretory products from the pores of eccrine glands. *Eccrine glands* are the sweat glands most abundant along friction ridge structures. Champod et al. state, "Secretions from eccrine and apocrine glands are mixtures of inorganic salts and water-soluble organic components that result in a water-soluble deposit. Secretions from sebaceous glands consist of a semisolid mixture of fats, waxes and long-chain alcohols that result in a non-water-soluble deposit."[5] *Sebaceous glands*, associated with hair follicles, are most abundant on areas of the skin that perspire, especially the scalp and face.[1,4] When one touches the face or scalp, the oils from these areas are transferred to the friction ridges of the fingers and palms; however, most often latent print residue is eccrine in origin.[4]

A latent fingerprint generally consists of both water-soluble and water-insoluble materials. After a latent is placed on a surface, it is subject to environmental effects, and its composition begins to change. The water constituent begins to evaporate when exposed to the air. A latent print can lose nearly 98% of its original weight within 72 h of deposition.

Arid, hot, and windy climates can speed up this process. Conversely, a humid climate slows down the process of latent print evaporation. Other environmental effects can be detrimental to latent prints deposited on a surface. For example, rain or snow can dilute or obliterate a friction ridge impression.

The substrate the print is deposited on also contributes to its durability and the changes in composition that occur over time. Inorganic latent components may produce a chemical reaction with the substrate, such as an oxidation reaction that may cause a fingerprint to become etched onto a metal surface. *Porous* substrates such as paper, cardboard, or raw wood are absorbent. Just as a sheet of paper will absorb water, so too will a sheet of paper absorb latent print deposits. When the latent print is absorbed into the porous material, the water begins to evaporate, but the residual components remain adhered to the fibrous matrix of the substrate (Figure 8.1).[6]

On *nonporous* substrates such as glass, metal, and plastic, latent prints remain on the surface (Figure 8.2).[6] They are therefore exposed to the elements and are more fragile than those on porous substrates. *Semiporous* items such as magazines, wax-coated paper cups, photographs, glossy paint, or painted/varnished wood have the properties of both porous and nonporous substrates. These substrates absorb the water-soluble deposits, though much

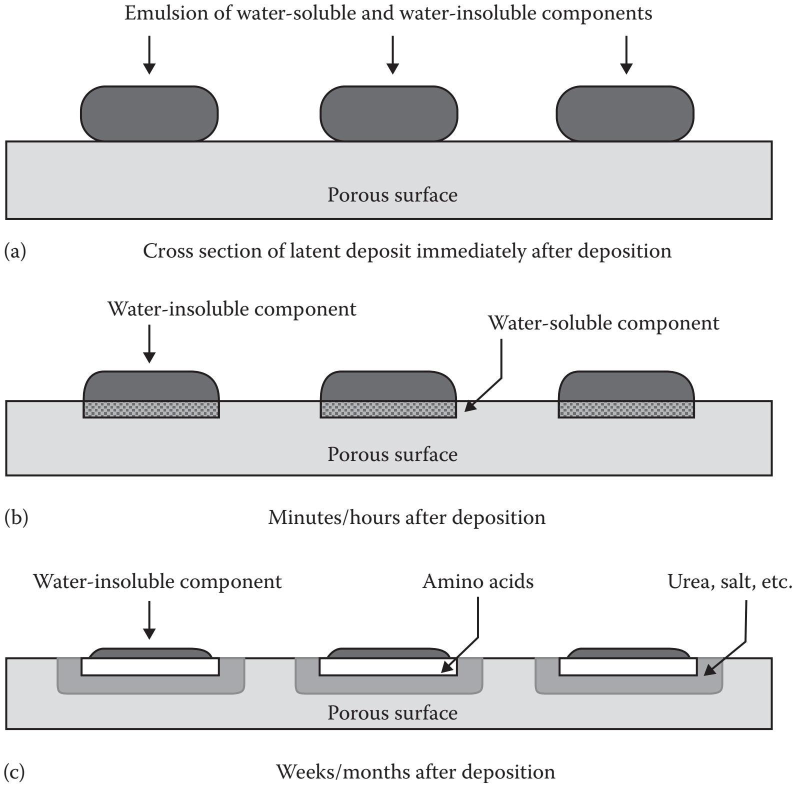
Emulsion of water-soluble and water-insoluble components
Porous surface
(a)
Cross section of latent deposit immediately after deposition
Water-insoluble component
Water-soluble component
Porous surface
(b)
Minutes/hours after deposition
Water-insoluble component
Amino acids
Urea, salt, etc.
Porous surface
(c)
Weeks/months after deposition

Figure 8.1 A cross section of fingerprint residues deposited on a porous substrate such as paper. When the fingerprint is deposited on the surface (a), the water-soluble components are absorbed into the substrate (b) and the water-insoluble components remain on the surface (c). (Reprinted with permission from Champod, C., *Fingerprints and Other Ridge Skin Impressions*. Boca Raton: Taylor & Francis, 2004, (Figure 4.2).)

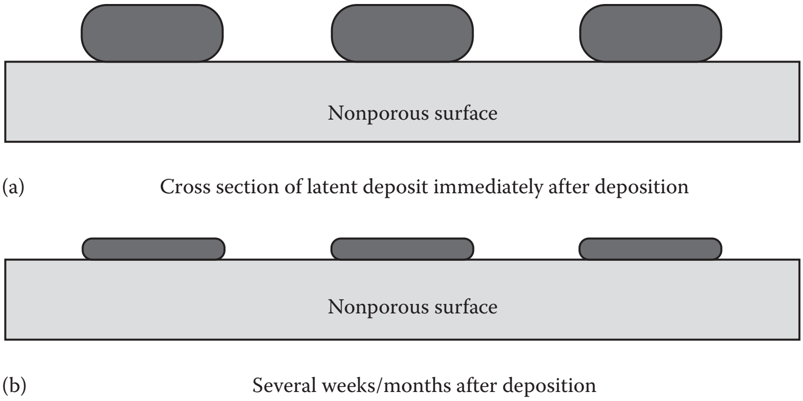
Nonporous surface
(a)
Cross section of latent deposit immediately after deposition
Nonporous surface
(b)
Several weeks/months after deposition

Figure 8.2 A cross section of fingerprint residues deposited on a nonporous substrate such as glass. When the fingerprint is deposited on the surface (a), both the water soluble and water-insoluble components remain on the surface (b). (Reprinted with permission from Champod, C., *Fingerprints and Other Ridge Skin Impressions*. Boca Raton: Taylor & Francis, 2004, (Figure 4.3).)

more slowly than porous items.[5] Water-insoluble components of friction ridge impressions sit on the surface similar to deposits on nonporous substrates.[5] Semiporous substrates are processed for latent prints using techniques utilized for both porous items and nonporous items since they have the physical properties of both.

8.2 Latent Print Development

Latent prints are made visible using a variety of optical, chemical, and physical development procedures. Many of these techniques initially arose from trial and error.[3] As science progressed, specializations developed in the form of numerous subdisciplines dedicated to addressing increasingly specific issues with latent fingerprint development. Contributions from these scientific subdisciplines have led to improved methods for developing latent prints. This burgeoning sophistication and increased scientific rigor have both improved existing methods of development and generated novel techniques for latent print development.[4]

There are a multitude of powders and chemical reagents available for processing latent fingerprints on porous, semiporous, and nonporous surfaces. There are also chemical reagents available for enhancing patent (visible) prints, which may consist of a bloody or oily matrix. The type of processing method chosen will depend on the condition and type of substrate; the composition of the latent fingerprint; your regional location and its unique atmospheric conditions; and the availability of powders, suspensions, and chemical reagents in your laboratory.

Research in fingerprint development is focused on finding chemical reagents that react with the various components of eccrine and sebaceous sweat to develop latent prints and make them visible. The resulting visible fingerprint may appear to be a specific color, or it may be fluorescent and therefore more readily visible with alternate light sources (ALSs) or lasers (Figure 8.3).

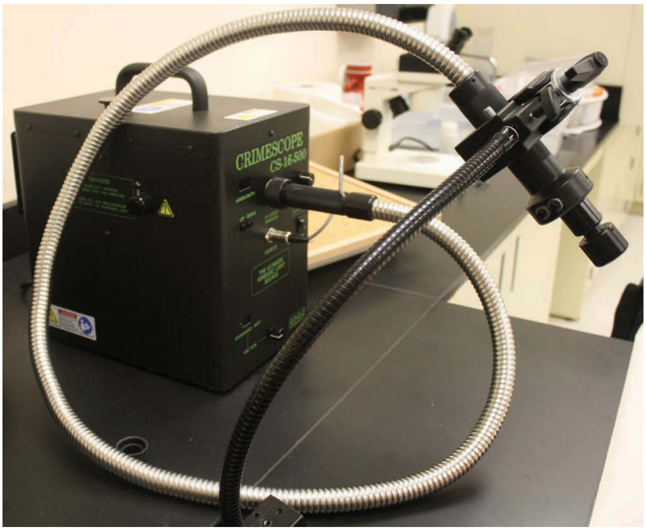

Figure 8.3 An alternate light source (ALS).

There are many different processing options. Some have proven superior to others, and many historically popular chemical reagents are no longer in common use. Some processing options work well in humid climates, but not in arid climates. Most items of evidence can be processed with multiple chemical reagents as long as those reagents are used in a specific order. See Appendix A for a list of sequential processing methods for various types of evidence.

Fingerprint development techniques are often broken down into physical processing methods and chemical processing methods. Physical processing implies that the scientist physically enhances the fingerprint using various fingerprint powders and brushes. Chemical processing refers to the use of chemical reagents. This text further subdivides fingerprint development techniques into four categories: physical processing methods, chemical processing methods on porous substrates, chemical processing methods on nonporous substrates, and "other" chemical processing methods. "Other" chemical processing methods will address how to develop bloody or greasy fingerprints, fingerprints on firearms, fingerprints on the adhesive side of tape, and other processing methods such as vacuum metal deposition. See Appendix B for a list of formulations for fingerprint reagents.

8.3 Health and Safety

It is important to remember health and safety considerations when any physical or chemical development technique is used. Even the use of the ALS or laser requires attention to safety protocols. Exposure may not have immediate effects, but may cause injury or illness after prolonged use if safety procedures and protocols are not adhered to. It is easy to become complacent when the use of these methods and reagents becomes routine. Your safety should be your number one priority both at a crime scene and in the laboratory.

While fingerprint powders may not seem hazardous, there are concerns associated with prolonged exposure. Many black fingerprint powders are made of carbon. Carbon powder is not inherently harmful unless you inhale large amounts of airborne powder on a regular basis, as coal miners do. Coal miners may suffer from a disease called pneumoconiosis, commonly known as "black lung," as a result of carbon dust exposure. Pneumoconiosis is "a disease of the lungs characterized by fibrosis and caused by the chronic inhalation of mineral dusts."[7] The size of the particle determines how deep the inhaled dust penetrates into the lungs and thus how harmful the dust is (Table 8.1).[7–10]

Dust particles less than 5 μm (0.005 mm) in diameter can penetrate all the way to the alveoli, the small sacs deep in the lungs that are responsible for oxygen and carbon dioxide gas exchange.[7] As shown in Table 8.2, most fingerprint powders are greater than 5 μm in width and therefore are unlikely to penetrate deep enough to accumulate in the alveolar sacs. However, extra care must be taken to avoid inhalation when working with white and fluorescent powders. While there has been no link between frequent exposure to fingerprint powders and pneumoconiosis, it is important to be aware of the potential health risks when using fingerprint powders on a regular basis or in a confined area.

Fingerprint powders are not all composed of variations of carbon powder. There are various colors (black, blue, red, white, etc.) and types of fingerprint powders (granular, magnetic, metallic, or fluorescent) that are mixtures of various organic and inorganic components (Figure 8.4). Some fingerprint powders that have historically been available by commercial forensic suppliers contain the following toxic inorganic chemicals: lead, mercury, cadmium, copper, silicon, titanium, and bismuth, though it is uncommon to find these powders today.[1] Most known hazardous ingredients are no longer used to make commercial powders; however, one must still exercise caution in order to avoid chronic health issues. The development of nanopowders (with nanoparticles less than 1 μm in diameter) may prove to be hazardous, though little research has been conducted on this topic. Several organic powder formulations have been developed from nontoxic components such as starch, fern spores, calcium sulfate, gum Arabic, Rhodamine B, turmeric, and fluorescein solution (also a bloodstain reagent and a component of many cosmetic products touted to give you a "glowing" appearance).[1,11,12]

Table 8.1 **The Depositional Location of Water Insoluble Inorganic Particles upon Inhalation**

Particle Size (μm)	Deposition Location After Inhalation
>15	Outer nasal passages
10–15	Nasal turbinates and pharynx (the areas just behind the nasal cavity)
5–10	Major airways, trachea, and major stem bronchi
<5	Penetration to alveoli

Table 8.2 **The Average Particle Sizes for Common Fingerprint Powder Types**

Fingerprint Powder Type	Particle Size (Average in μm)
Black	20–33
Black magnetic	11–18
White	0.55–0.85
Fluorescent	1–2.5
Metal flake	10

Figure 8.4 Bronze, gold, and silver fingerprint powder.

Many chemical reagents are hazardous when absorbed through the skin, ingested, splashed into the eyes, or inhaled. Adherence to basic laboratory safety procedures negates these hazards. Potential health hazards and environmental hazards are listed in the applicable *material safety data sheet (MSDS)* or *safety data sheets (SDS)* (which replaced the MSDS in 2015). An overview of these hazards is tabulated in Appendix C. The MSDS or SDS form indicates potential fire, chemical and health hazards of a given chemical reagent. It can be referenced online, though hard copies are often available in the forensic laboratory.

Reagents such as Rhodamine 6G, crystal violet, and Ardrox have been labeled as possible carcinogens. Cyanoacrylate ester, or superglue®, is potentially hazardous as it may release hydrogen cyanide and cyanide gas at high temperatures above 200°C (392°F).[13] Ninhydrin, the most frequently used reagent in the United States for developing latent prints on porous materials, has applications in other fields. In the medical field, it is used as the "ink" in surgical marking pens, though it was found to cause eczema or allergic reactions in some people.[14–16] Therefore, care must be taken to avoid skin exposure to ninhydrin.

The general rule when working with chemicals is to limit exposure and adhere to all safety precautions. *Nitrile gloves* should be worn at all times (Figure 8.5). (Remember that even gloved hands can wipe away delicate fingerprints from a nonporous surface if the item is handled on fingerprint-bearing surfaces.) *Safety glasses* with side shields or chemical-resistant safety goggles will protect the eyes (Figure 8.6). A laboratory coat with long sleeves offers minimal skin protection (Figure 8.7). A *particulate* or *ventilated mask* will prevent excess inhalation (Figure 8.8). Proper ventilation through the use of a *fume hood* (when working with chemical reagents) or *downflow workstation* (when working with powders) will also prevent inhalation. A downflow workstation is similar to a fume hood, but instead of pulling air up through the unit into a filtration system, it pulls air down through a perforated work surface (Figure 8.9). As soon as fingerprint processing is complete, the hands should be washed thoroughly with soap and water. Clothes should be laundered as soon as possible.

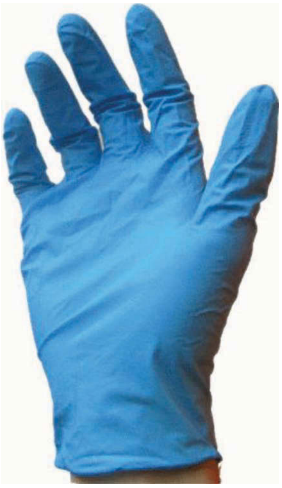

Figure 8.5 Nitrile glove.

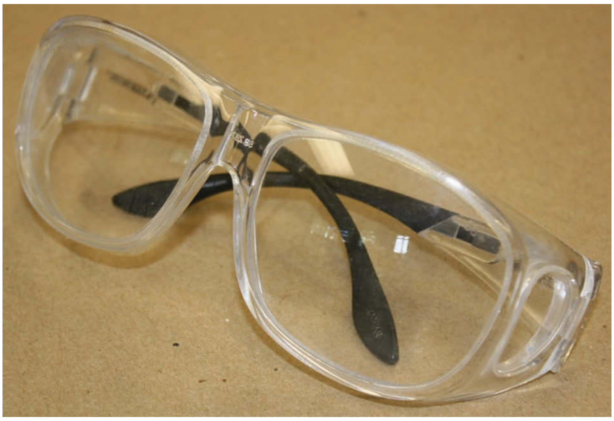

Figure 8.6 Safety glasses.

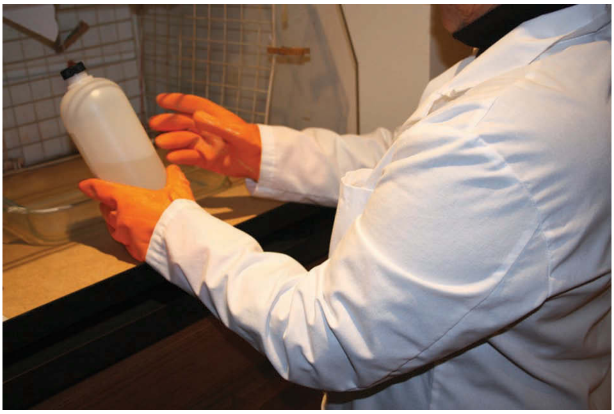

Figure 8.7 A forensic scientist handles chemical reagents with gloves and a long-sleeved laboratory coat.

Figure 8.8 A particulate mask protects a forensic scientist from inhaling particles such as fingerprint powders.

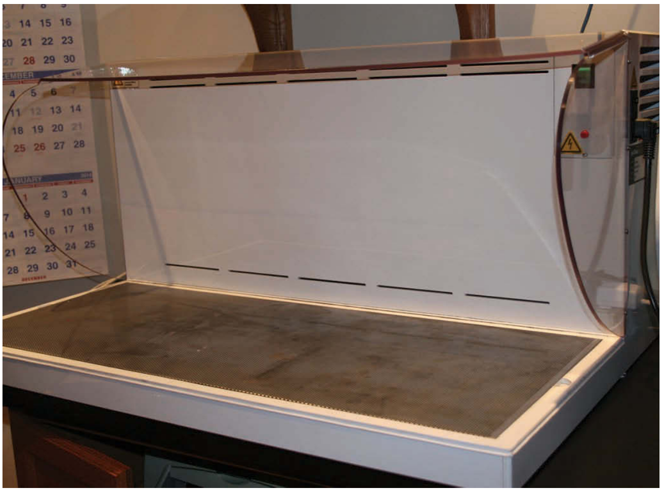

Figure 8.9 A downflow workstation is a fume hood that pulls air and fingerprint dust down through a perforated work surface.

Chemicals and powders should always be stored, cleaned, and disposed of properly. A cool, dry place away from open flame is an appropriate area for storing chemical reagents and powders. Flammable materials should be stored in a *flammables cabinet* (Figure 8.10). Chemicals should all be properly labeled and MSDS or SDS documentation made available for all reagents used. All chemicals should be disposed of properly. Spills should be cleaned up as recommended by the appropriate MSDS or SDS. Equipment such as fume hoods, eye wash stations, and drench showers should be regularly tested and maintained. Common

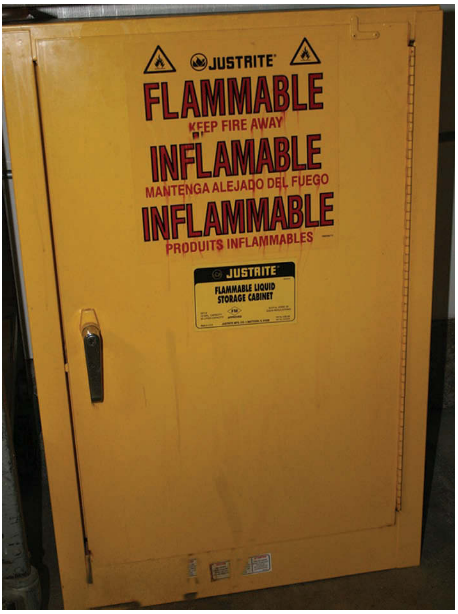

Figure 8.10 Flammable reagents are stored in a flammables cabinet.

sense and attentiveness, as well as a general working knowledge of chemistry, should diminish the possibility of exposure or long-term detrimental effects.

Light sources of varying intensities and wavelengths are used extensively in many forensic subdisciplines, and fingerprint analysis is no exception. Just because exposure to light does not immediately cause acute detrimental health issues or pain does not mean it is harmless. The detrimental effects of ultraviolet (UV) radiation are commonly experienced as sunburn. An ALS or lasers can cause eye damage as well as skin damage. Light of different wavelengths should always be viewed through the appropriate colored glasses or filter. Gloves and a long-sleeved laboratory coat should be worn at all times. Prolonged skin exposure may lead to skin cancer in the same way that skin cancer may be caused by too much unprotected exposure to the sun. Regardless of the fingerprint processing or visualization technique used, personal safety is a matter of both education and due diligence.

8.4 General Approach to Evidence Processing

Most items can be processed using more than one chemical reagent or a variety of both physical and chemical processing methods. Some chemical reagents have to be used in a specific order. This is known as *sequential processing*, which means the processes must be done in a particular sequence or order. Some chemicals may inhibit other chemicals. Examples of these sequences will be presented in the chapters that follow.

A vast majority of forensic laboratories do not use all the processes described in this text. In fact, most laboratories use only a few select reagents. Forensic scientists also have personal preferences based on professional experience and training. Some laboratories are restricted by their limited budgets. Some laboratories do not have access to certain reagents. Other laboratories have standard operating procedures (SOPs) that outline specific techniques used in specific circumstances. Some laboratories are also limited by heavy caseloads and have little time to process items using multiple reagents.

Regardless of the processing method chosen, be it physical or chemical, there are procedures that are used in order to protect the integrity of the evidence and ensure success. Examiners from other disciplines should be consulted prior to processing certain items to prevent damage to or loss of other forensic evidence such as DNA, toolmarks, firearms evidence, or trace evidence.

Documentation is critical for recording each step in the latent print development process. Documentation includes taking thorough laboratory notes, taking photographs, filling out the necessary forms and worksheets, and writing final reports based on your actions and analyses. These documentation methods are discussed in Chapter 14. How you document your cases depends on your agency's *SOPs* and protocols. The following is an example of general steps that may be followed when processing items of evidence for latent prints:

1. Remove the evidence from its packaging.
2. Photograph the item before processing.
3. Visually inspect the surface of interest with optical techniques such as white light, oblique lighting, ALS, laser, and/or reflective ultraviolet imaging system (see Chapter 9).
4. Photograph any visible fingerprints.
5. Developmental process #1 (per SOPs)
6. Photograph any visible fingerprints.
7. Developmental process #2 (per SOPs)
8. Photograph any visible fingerprints.
9. Developmental process #3 (per SOPs)
10. Photograph any visible fingerprints.
11. Repackage in the original evidence bag or box and seal the package.

The purpose of thorough documentation is to record the condition of the item of evidence prior to and following each step. It also ensures all forensic evidence is recorded thoroughly.

8.5 DNA Analysis

As DNA technology becomes more and more sensitive, fingerprint examiners must be more careful not to contaminate or degrade a possible source of DNA evidence. Gloves should always be worn and changed frequently. Particulate masks should be worn if the examiner might breathe, sneeze, or cough on the evidence. And only chemical processing methods that will not degrade or destroy DNA evidence should be used if the item will be sent for DNA analysis following latent print processing.

Extensive research has been done to examine the effects of fingerprint reagents on DNA yields. Recent studies have found that most current methods of fingerprint development do not have detrimental effects on DNA. While the yield of DNA may be lower following fingerprint processing, a DNA analyst can still obtain enough DNA for forensic analysis following development with the following common fingerprint reagents: ninhydrin, 1,8-diazafluoren-9-one (DFO), vacuum metal deposition, Amido black and cyanoacrylate (superglue) fuming.[18–26] DNA recovered after indanedione processing, however, must be completed within 6 days of applying the reagent.[23] After that time period, DNA is not viable. Exposure to an ALS also had no detrimental effect on DNA processing with the exception of shortwave UV radiation, which is known to degrade DNA after prolonged exposure.[26] Physical developer and silver nitrate, processes for processing fingerprints on porous surfaces, degrade DNA. Physical developer or silver nitrate should not be used if DNA analysis is anticipated.[26]

8.6 I Had a Case: The Dangers of Light

The Reflective Ultra Violet Imaging System (RUVIS) is a nondestructive latent print visualization technique that utilizes short-wave UV light. Latent prints, especially those developed with cyanoacrylate ester fumes, appear to glow green against a black background. This technique is especially useful on nonporous surfaces with background interference or on reflective surfaces.

Because the technique utilizes short-wave UV light, which can be harmful to the skin, the fingerprint analyst using this technique donned nitrile gloves, a lab coat with long sleeves, UV safety goggles, and a UV face shield. While examining a stack of CDs, the sleeves of the examiner's lab coat did not reach to the individual's wrists. To examine the CDs, the examiner looked up at a computer monitor where the RUVIS image was displayed.

The fingerprint examiner suffered sunburn around the wrists because her wrists were exposed to the UV light. Also, because the examiner was looking up at the computer monitor, the UV light bouncing off the reflective surface of the CDs was hitting her neck underneath the face shield, resulting in further sunburn around the neck. It is often not enough to wear the proper protective equipment in the laboratory. It is also necessary to remain judicious to protect oneself from laboratory hazards at all times.

8.7 Chapter Summary

The quality of fingerprints recovered from a crime scene or item of evidence depends on the texture and permeability of the substrate, the quantity of material deposited, the composition and age of the latent fingerprint, environmental effects, distortion and the methods of development, documentation, and collection. Latent print deposits are mixtures of water-soluble and water-insoluble deposits. Fingerprints placed on porous substrates are absorbed, while fingerprints placed on nonporous substrates remain on the surface and are more easily obliterated.

It is important to adhere to your laboratory's safety procedures and protocols and to educate yourself about all potential hazards. Regardless of the processing method used, there are procedures that must be adhered to in order to protect the integrity of the evidence; this includes handling the evidence responsibly and safely and documenting each step of the analysis. If an item of evidence will be submitted for DNA testing following latent print processing, do not use physical developer or silver nitrate or expose the item to shortwave UV radiation.

8.8 Review Questions

1. What are four factors that affect the quality of prints recovered from the crime scene or items of evidence?
2. Secretions from which glands contribute the most water-insoluble matrix to the latent print deposit?
3. Secretions from which glands contribute the most water-soluble matrix to the latent print deposit?
4. Name three common porous evidentiary items you may find at a crime scene.
5. Name three common nonporous evidentiary items you may find at a crime scene.
6. Name two common semiporous evidentiary items you may find at a crime scene.
7. What are three important items of personal protective equipment that must be worn at all times when working in a laboratory environment?
8. What additional personal protective equipment can be worn if you are concerned with DNA contamination or are working with biological fluids?
9. What are the general steps that are taken when processing items of evidence for fingerprints?
10. Which fingerprint development processes must not be used if the item is to be submitted for DNA analysis?

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Forensic Light Sources

9

Bloodstains, semen, bruises, bone fragments, questioned documents, flammable residues, fibers and fingerprints all merit examination with a forensic light source or laser.[1]

LEARNING OBJECTIVES

- Understand the importance of conducting a visual examination of evidence prior to latent print processing.
- Understand the physics of light and how it interacts with matter.
- Distinguish between and understand the applications of the alternate light source, laser, and reflective ultraviolet imaging system.

9.1 Visual Examination

Light is one of the forensic scientist's most potent tools. It is used throughout latent print development to visualize latent prints. Regardless of the substrate, matrix, or circumstance, all evidentiary items and surfaces must be visually examined using light before any chemical or physical process is initiated. Visual examination is a nondestructive process. It allows visible fingerprints to be documented before fingerprint powder or chemicals are applied. While powders and chemical reagents are meant to enhance latent prints or make them visible, it is also possible to accidentally obliterate latent prints using those same procedures.

A visual examination is not only performed under white overhead lights or in natural lighting conditions. A variety of light sources are used. A simple flashlight can be shone onto an evidentiary item at various angles to create light and shadow across a surface. Light shone across an object at an oblique angle is known as *oblique lighting*. Oblique lighting is often the best way to visualize latent, plastic, and patent fingerprints on an object (Figure 9.1). Light is shone at a low angle in order to see details on the surface where light and shadow create contrast. Oblique lighting is used throughout the forensic sciences to observe details in shoe and tire impressions, firearm evidence, toolmarks, and various other types of evidence.

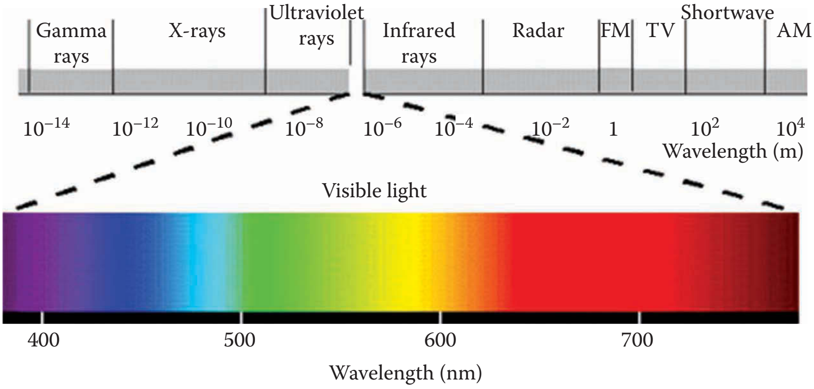
If a thorough visual examination of the surface reveals a latent print, the print is photographed. Only then may a fingerprint analyst proceed with chemical and physical processing methods. There are several other stages of latent print processing when the fingerprint analyst uses light as a nondestructive technique to reveal fingerprints. Besides white light, the fingerprint analyst uses different colors (wavelengths) of light, ultraviolet (UV) light, and infrared light to view evidence without obliterating fingerprints.

Figure 9.1 A forensic scientist examines an item of evidence with oblique lighting.

9.2 The Physics of Light

Forensic scientists use light of different colors to see details and view luminescent chemical reagents. Light is a form of electromagnetic energy that travels in waves. Light energy is only one portion of a spectrum, or range, of wavelengths that includes X-rays, gamma rays and radio waves (Figure 9.2). Wavelengths are measured in nanometers (nm). A wavelength can range from picometers (1×10^{-12} m) to many meters in length (such as radio waves). The shorter the wavelength of light, the greater the energy it produces. For example, radio waves are very low energy compared with shortwave ultraviolet light, which can cause burns with skin exposure.

The way humans perceive light and color is based on how light interacts with matter. When light hits a surface, it is reflected, transmitted, or absorbed by the surface (Figure 9.3). If all light is absorbed into the surface of an object, it is perceived as black in color. Most of the light that passes through translucent or transparent objects is transmitted, meaning it passes through without being absorbed or reflected. If a flashlight is shone at a window, the transmitted light passes through to the other side. When light is reflected off an object, it



Gamma rays
X-rays
Ultraviolet rays
Infrared rays
Radar
FM
TV
Shortwave
AM
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
Wavelength (m)
Visible light
400
500
600
700
Wavelength (nm)

Figure 9.2 The color spectrum (the range of colors visible to the human eye) is a narrow range of wavelengths within the electromagnetic spectrum.

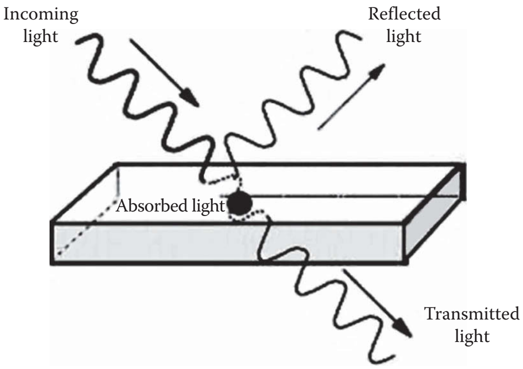


Figure 9.3 A schematic drawing demonstrating how light is reflected, absorbed, and/or transmitted when it interacts with a surface.

bounces off the surface in different ways. Depending on the texture and reflectivity of the surface, the human eye may perceive that light as a color.

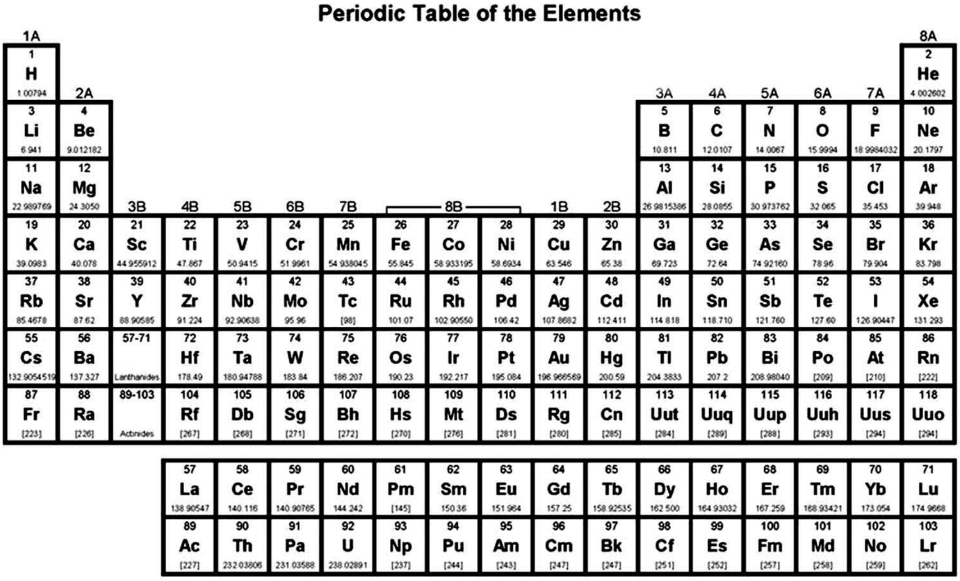
The spectrum of colors that makes up a rainbow is the same range of wavelengths humans can perceive with the naked eye. This range, known as the *visible spectrum*, contains light with wavelengths between 390 and 700 nm. Each color of the rainbow represents a short range of wavelengths within the visible spectrum of light; for example, green light consists of wavelengths between 490 and 575 nm. The color humans perceive is a result of the wavelength of light that reflect off a surface. A red rose reflects light at wavelengths between 620 and 700 nm, the red portion of the spectrum. What we perceive as white light is in fact a mixture of colors. Black objects absorb light and therefore do not reflect light at a wavelength within the visible color spectrum.

9.3 Fluorescence and Phosphorescence

The forensic sciences utilize not only the visible color spectrum, but also physical properties of light known as fluorescence and phosphorescence. Both of these properties are the result of light interacting with substrates in different ways. Prior to discussing the use of fluorescence and phosphorescence in the field of fingerprint analysis, it is important to review the chemistry behind how objects are formed.

Matter is, at the most basic level, composed of molecular compounds formed of elemental atoms. For example, water—H_2O—is a molecular compound formed by two elements: hydrogen (H) and oxygen (O). Each element in the periodic table has a unique *atomic number*. The atomic number is the number of protons or electrons in an atom. For example, oxygen has an atomic number of eight, indicating it has eight protons and eight electrons (Figure 9.4). Protons have a positive charge and electrons have a negative charge. The charge is balanced in its ground, or normal, state. *Atomic mass* is determined by the number of protons plus the number of neutrons in the nucleus, the core of the atom. Neutrons are neutral. They have no charge.

Light not only travels in waves but also acts on matter as a unit of energy known as a *photon*. A photon of energy reacts with surfaces at the atomic level. An atom or molecule absorbs the photon's energy and changes from its natural ground state to a



Periodic Table of the Elements

1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.0067	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989769	12 Mg 24.3050											13 Al 26.9815386	14 Si 28.0855	15 P 30.973762	16 S 32.065	17 Cl 35.453	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955912	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938045	26 Fe 55.845	27 Co 58.933195	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.96	43 Tc [98]	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.293
55 Cs 132.9054519	56 Ba 137.327	57-71 Lanthanides	72 Hf 178.49	73 Ta 180.94788	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.084	79 Au 196.966569	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98040	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra [226]	89-103 Actinides	104 Rf [267]	105 Db [268]	106 Sg [271]	107 Bh [272]	108 Hs [270]	109 Mt [276]	110 Ds [281]	111 Rg [280]	112 Cn [285]	113 Uut [284]	114 Uuq [289]	115 Uup [288]	116 Uuh [293]	117 Uus [294]	118 Uuo [294]
			57 La 138.90547	58 Ce 140.116	59 Pr 140.90765	60 Nd 144.242	61 Pm [145]	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92535	66 Dy 162.500	67 Ho 164.93032	68 Er 167.259	69 Tm 168.93421	70 Yb 173.054	71 Lu 174.9668
			89 Ac [227]	90 Th 232.03806	91 Pa 231.03588	92 U 238.02891	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]

Figure 9.4 The periodic table of the elements.

more energetic, "excited" state. The atom is naturally inclined to seek its ground, neutral state. In order to restore the balance of energy within the particle, it emits that absorbed energy as a photon. The energy absorbed and emitted by the particle is known as electromagnetic radiation whether it is visible light, UV, infrared, X-ray, microwaves, or radio waves.

When the molecule absorbs energy, some of that energy is transferred to surrounding molecules. Because some of the energy is used up in this process, the emitted electromagnetic radiation has less energy than the absorbed electromagnetic radiation. As was mentioned earlier, light waves with longer wavelengths have lower energy. Light waves with shorter wavelengths have higher energy. When light is absorbed at one wavelength, and loses energy as it interacts with matter, it is emitted at a longer wavelength than the absorbed light (Figure 9.5). This process creates *luminescence.*

Luminescence includes both *fluorescence* and phosphorescence. When molecules are excited by a specific color, or wavelength of light, they luminesce in a way that is specific to the chemical composition of that molecule. Surfaces and chemicals that fluoresce will only glow when energy is constantly applied to the surface. For example, if a chemical fluoresces only under yellow light, it will stop fluorescing as soon as that yellow light is removed. DFO and Rhodamine 6G are fluorescent chemicals that fluoresce under green light (Figure 9.6). When the green light is removed, the chemical no longer glows.

Phosphorescence occurs when the surface continues to glow even after the energy source is removed. Luminol is a chemical used to visualize latent bloodstains and enhance patent bloodstains at crime scenes (Figure 9.7). When the chemical is sprayed onto a surface, it reacts with the iron in hemoglobin and glows blue. Luminol continues to glow on its own for approximately 30 s without applying any constant energy source. This phosphorescence is only visible in the dark. Though phosphorescence is used in the forensic sciences, fingerprint analysts use fluorescent reagents frequently in the laboratory.

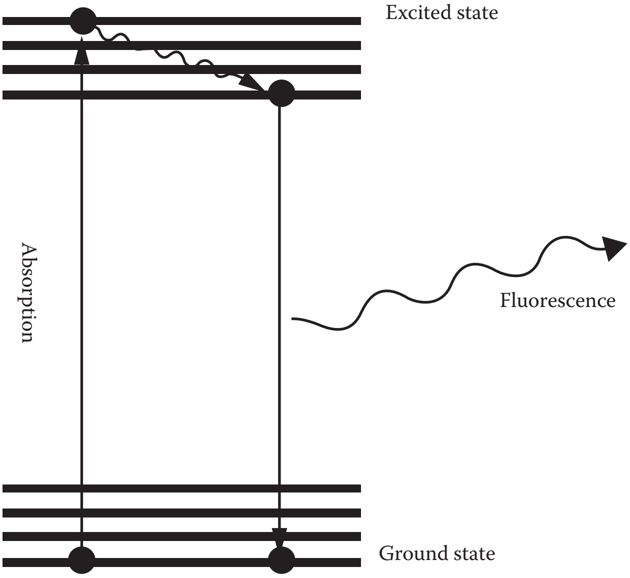


Figure 9.5 Fluorescence is observed when light is absorbed, loses energy as it interacts with matter, and is emitted at a longer wavelength.

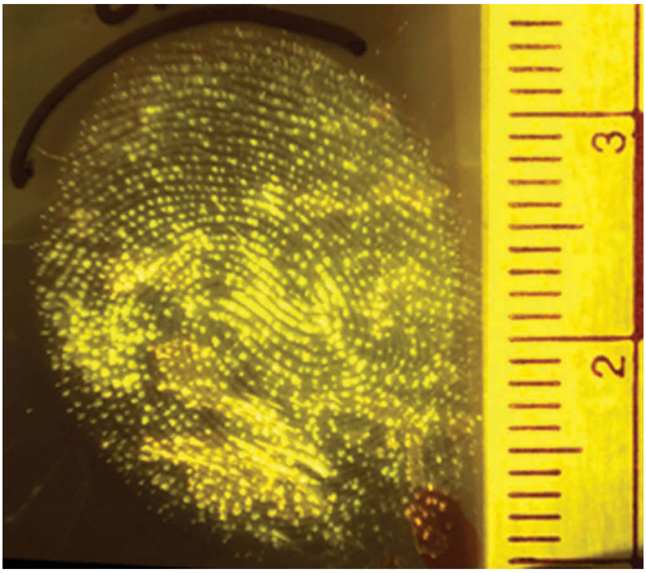


Figure 9.6 A fingerprint developed with Rhodamine 6G.

Fluorescence is not viewed with the naked eye. Instead it is viewed through filters or special glasses. A forensic light source provides energy in the form of monochromatic light (light of a single color or narrow range of wavelengths). The light that comes from the forensic light source is known as *incident light*. When the incident light hits the substrate, it is reflected. This is known as *reflected light*. The angle at which the incident light hits the

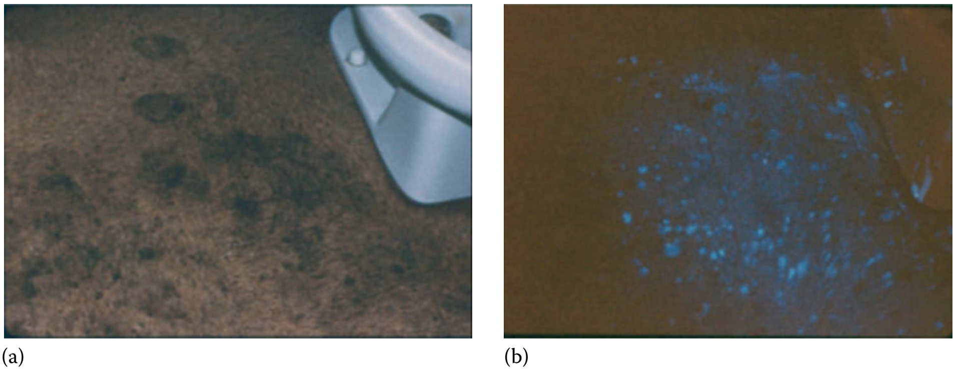


Figure 9.7 The bathroom floor at a crime scene before (left) and after (right) treatment with Luminol (Photographs courtesy of Wilson Sullivan).

surface (the angle of incidence) is equal to the angle at which it is reflected off the surface (the angle of reflection).

When incident light hits the friction ridges that have been treated with fluorescent chemicals or powders, the light bounces off in many different angles. This light is referred to as *scattered light*. A *barrier filter* is placed between the human eye and the surface. The barrier filter blocks the reflected light, while the scattered light passes through the filter and is perceived as fluorescence (Figure 9.8).

Filters are often laboratory safety glasses of different colors that are specific to the chemical reagent or powder, the color of the light source, and the color of the fluorescent emission (Figure 9.9). Filters block the light source and only allow the fluorescing light from the fingerprints to pass through. Yellow glasses are used with blue light. Orange glasses are used with blue/green light. Red glasses are used with green light. Table 9.1 illustrates the most common fluorescent reagents used in the fingerprint laboratory, the corresponding

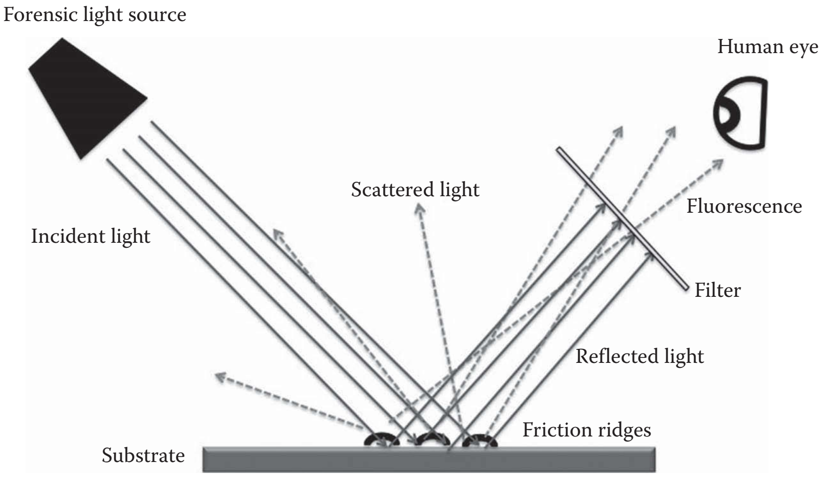


Figure 9.8 This schematic demonstrates how incident light from a fluorescent light source interacts with a latent print treated with a fluorescent chemical reagent. The incident light reflects off the surface and is observed through the barrier filter as fluorescence.

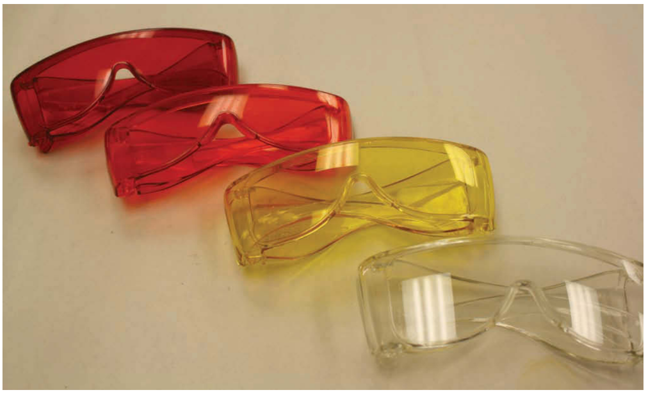


Figure 9.9 Colored safety glasses are worn as filters in conjunction with forensic light sources.

Table 9.1 Wavelengths, Colors of Light, and Their Associated Filters and Fluorescent Fingerprint Reagents

Wavelength (nm)	Light Color	Filter Color	Fluorescent Fingerprint Reagent/Powder
350–400	UV	UV (clear)/ yellow	Ardrox, Basic Yellow 40, RAM
400–455	Blue	Yellow	Yellow/green fluorescent powder, Acid Yellow 7
445–515	Blue/ green	Orange	Acid Yellow 7, Orange fluorescent powder, Rhodamine 6G, MBD, RAM
515–575	Green	Red	RAM, Rhodamine 6G, 1,8-Diazafluoren-9-one, Indanedione, Redwop (red fluorescent powder)

wavelengths/colors of light used to excite the chemicals, and the barrier filters used to view the resulting fluorescence.

Fluorescent reagents are useful when the background substrate is too dark or patterned to see the colored products of visible reagents (Figure 9.10). It is also useful when the reaction product is a similar color to the background. For example, a superglue® fumed fingerprint is white in color. If a white coffee mug is processed with superglue fumes, the resulting latent prints are difficult to visualize, as they are also white in color. If a fluorescent chemical reagent is used on that mug, the latent prints will fluoresce, or glow. It will be easier to see with the naked eye as well as photograph. Fluorescence creates contrast. However, if the substrate the fingerprint is placed on is itself fluorescent, the fingerprint will not stand out against the background.

Forensic light sources are also useful tools for visualizing blood on various surfaces. Hemoglobin absorbs light energy. Bloody fingerprints will therefore absorb long-wave UV light and some visible and near-infrared light. Because it absorbs light, the blood will appear black against the background. Blood can thus be enhanced through nondestructive means by simply viewing it under various colors of light with various filters. The blood should not be exposed to light energy for too long, especially short wave UV light, as it may degrade the DNA.[2]

Colored glasses or filters are not only used to visualize fluorescence. They are also used to protect the eyes from electromagnetic radiation. It is important to protect the skin

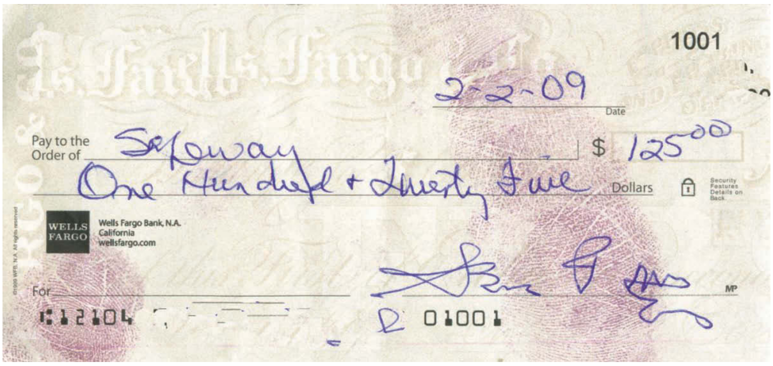


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Figure 9.10 Ninhydrin fingerprints developed on a check.

as well. Any exposed skin should be covered with nitrile gloves and a long-sleeved lab coat. Higher-energy, shorter-wavelength light is especially hazardous. Therefore, great care should be taken especially when using shortwave UV light.

9.4 Forensic Light Sources

In the 1930s, researchers developed a fingerprint powder that fluoresced under UV light.[3] *Forensic light sources* (FLS) were first introduced to the forensic community at large in the late 1970s when Dalrymple et al. published a paper on the inherent fluorescence of fingerprint residue.[4] Some of the compounds in fingerprints glow under different wavelengths of light without the aid of chemical processing. However, items are not often viewed with forensic light sources prior to processing because inherent fluorescence is usually very weak and does not occur frequently.[5–7] Fingerprints treated with fluorescent reagents or powders luminesce strongly under various wavelengths of light.

The light source utilized in early research studies was an argon ion laser. *Laser* stands for light amplification by stimulated emission of radiation. While modern lasers are not very portable, they are small and fit on a laboratory bench top. The advantage to lasers commonly found in forensic laboratories is that they provide a monochromatic light source at ~532 nm. This results in a powerful beam of green light ideal for visualizing many fluorescent fingerprint powders and reagents. Evidence visualized at this wavelength should be viewed through an orange barrier filter or with orange safety glasses.

In the 1980s, companies in Australia, Great Britain, and Canada developed forensic light sources that could be dialed to different monochromatic wavelengths.[8] These units are known as *alternate light sources* (ALSs) (Figure 9.11). An ALS provides strong white light and various bypass filters that correspond with different segments of the visible spectrum from ultraviolet to red.

Since the 1990s, with advances in technology such as light-emitting diodes, portable ALSs have been developed.[3,9] *Light-emitting diodes* (LEDs) are powerful light sources beneficial due to their small size, increased efficiency, and durability. ALS units are now so portable that many resemble flashlights, which can be readily carried throughout a crime scene or laboratory (Figure 9.12). LED forensic light sources and lasers complement each other. Dalrymple and Almog found that each light source has "the potential to detect

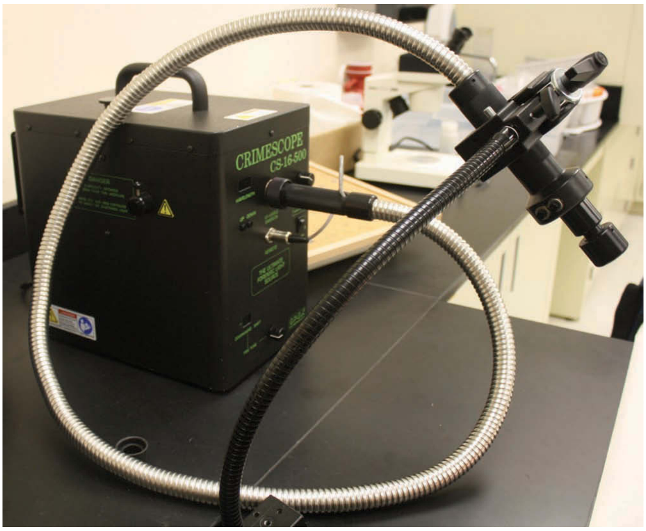

Figure 9.11 An alternate light source.

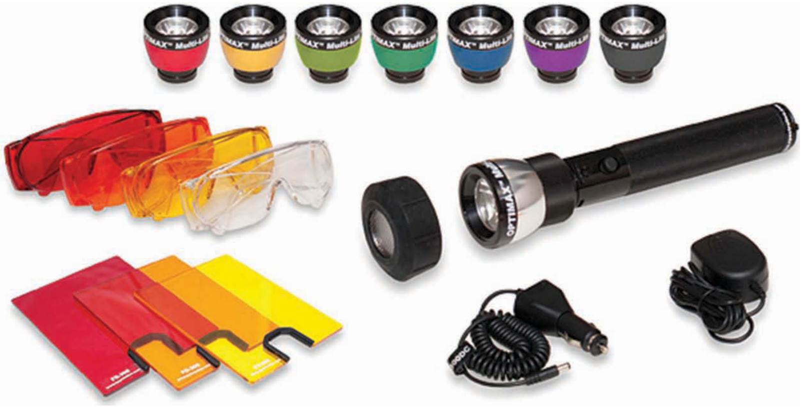

Figure 9.12 The Spectroline® Optimax™ Multi-Lite is a hand-held alternate light source with interchangeable heads providing single-wavelength UV, blue, green, orange, red, and white illumination.

evidence missed by the other."[10] Forensic light sources are routinely used in the forensic laboratory as part of almost every processing sequence to develop fingerprints on a wide variety of substrates.

9.5 Reflective Ultraviolet Imaging System

The reflective ultraviolet imaging system (RUVIS) pictured in Figure 9.13 is an optical technique that utilizes UV light in a narrow band of the UV spectrum to visualize friction ridges (Figure 9.13). RUVIS prints most often appear to glow green on a black background when the incident light is shone on the object at an acute or oblique angle. The background

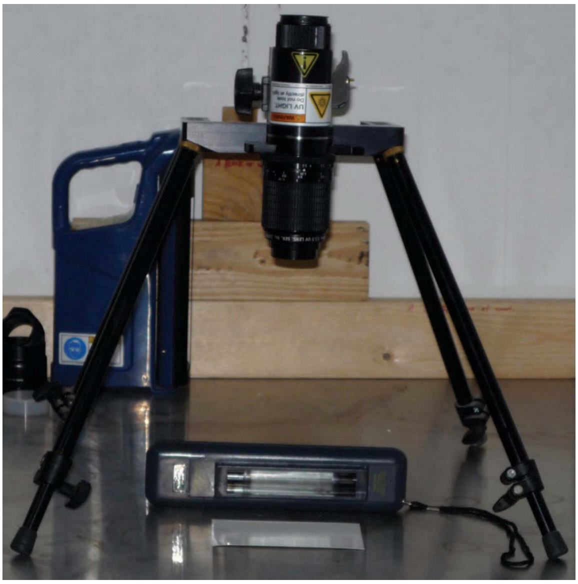

Figure 9.13 The RUVIS system pictured comprises an intensifier on a stand and a shortwave UV light.

will appear black because the substrate absorbs most of the incident light. Light shone perpendicular to the surface may appear dark on a green background.

The system requires a shortwave UV light source and the RUVIS unit itself, a cylindrical device known as an *intensifier*. The intensifier has a UV filter at one end and a monocular eyepiece at the other end. The analyst looks through the eyepiece of the intensifier to view the friction ridges. The laboratory analyst must wear yellow laboratory safety glasses in order to view the RUVIS image safely. A RUVIS intensifier can also be hooked up to a computer monitor so the analyst can view the friction ridge impression enlarged on a screen. The RUVIS intensifier is portable. It can therefore be hand-carried throughout the laboratory or crime scene.

Figure 9.14 demonstrates how fingerprints are visualized with the RUVIS. A shortwave UV light source (~254 nm) is used to shine incident light onto an object.[11] Areas of a flat substrate that do not have latent prints on them will reflect and absorb the UV light. If there is a latent print on that object, or any other residues with dimension and height, the light that hits the friction ridges will scatter. Latent prints can be ~250–700 nm high, depending on the matrix and substrate.[11] Most of the shortwave UV light is absorbed by the substrate, and thus appears black, while the scattered light is visualized. The scattered UV light passes through a UV band-pass filter, which only lets UV light in a narrow spectrum pass through. All other wavelengths of light are blocked.

Because only a narrow band of scattered UV light penetrates the filter, the signal must be converted to visible light and amplified to be visible to the human eye. This is the function of the intensifier. It intensifies the signal 70,000×, similar to military night vision technology, making a faint image easily visible to the human eye (Figure 9.15).[11,12] Since only the scattered light is viewed, the light source must be shone at various angles onto the substrate to obtain the best image. A latent print that is visible when the UV light is directed at the surface at a 45° angle might be invisible when the light is held at a 30° angle. Adjusting the angle of incidence of the light source increases contrast in the latent print.

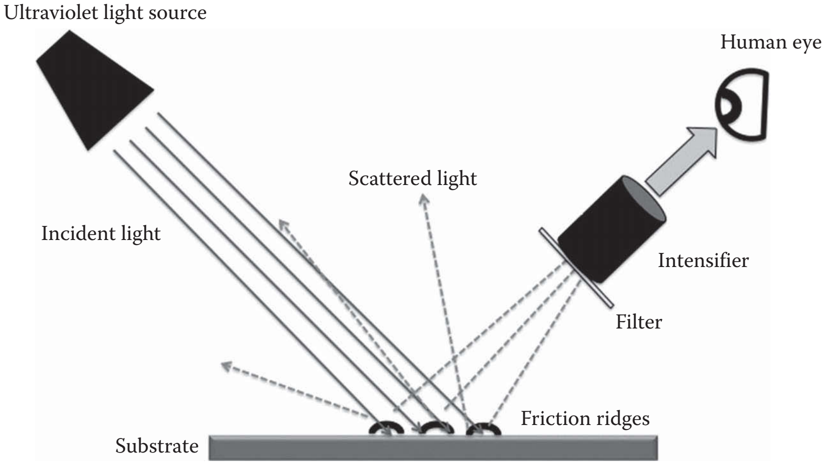

Figure 9.14 This schematic demonstrates how the incident light from a shortwave ultraviolet light source interacts with a latent print. The scattered light is observed through the intensifier.

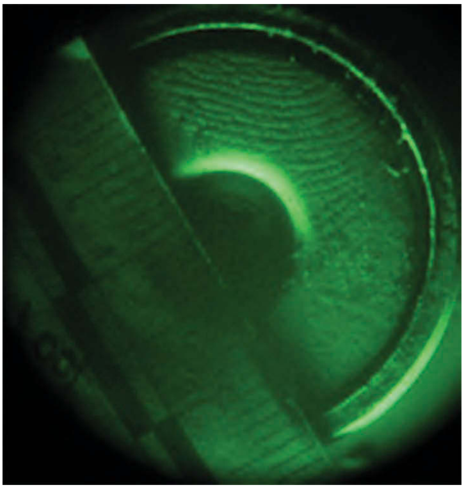

Figure 9.15 A RUVIS fingerprint on a magnet.

RUVIS is a nondestructive process that can be used prior to any physical or chemical processing techniques. It has been used since the late 1980s in many forensic applications.[9] Because it utilizes scattered light from features on an object, it can also be used to highlight indentations or irregularities in a surface, such as wounds, bite marks, and bruising on live and deceased victims; biological fluids such as semen and saliva; indented writing and ink analysis in questioned documents; and trace evidence such as fibers and hairs.[9,11] While RUVIS has been shown to illuminate untreated latent prints, it provides significant contrast when used after superglue® fuming.[11–13]

Only latent prints on the surface of an item are detected by the RUVIS, regardless of the type of substrate they are detected on or the color of the substrate. If the latent print residue is not deposited on the surface, the RUVIS will not be effective. Porous items, therefore, cannot be analyzed with a RUVIS since the matrix of the latent print is absorbed into the substrate. Another limitation to RUVIS is the texture of the surface. If a surface is textured, the light will scatter across the entire surface, not just the friction ridges, and the print will not be readily visible on the surface.

RUVIS has been used in many applications and has proven successful on postblast explosive materials, such as improvised explosive devices (IEDs) and vehicle-borne IEDs (VBIEDs).[14,15] Latent prints were visualized before and after superglue fuming.[15] Gardner states, "Based on the reported results, it is believed the RUVIS UV imager could be used to quickly (and safely) locate and capture latent prints on ordnance (explosive materials) and associated materials prior to on-site demolition. Obtaining these latent prints would assist in identifying those responsible for the construction, storing, emplacement and use of IEDs."[14]

The shortwave UV light used with RUVIS is especially harmful and all skin surfaces should be covered at all times. The short wavelength corresponds to high-energy electromagnetic radiation. A face shield and/or neoprene hood can provide extra protection for the face and neck. Regardless of the forensic light source used, proper personal protective equipment must be worn at all times.

9.6 I Had a Case: The Power of RUVIS

In 2004, an improvised explosive device detonated near Baghdad, Iraq, causing the death of a United States soldier. That device, consisting of a fuel jug filled with explosive material, was wrapped in plastic sheeting and packing tape. At the time of the incident, Explosive Ordnance Disposal technicians—those service members charged with detecting, disarming, detonating, and disposing of explosive materials—collected the bomb components.

Almost a decade later, the bomb components were submitted to a forensic laboratory. A latent print analyst processed the components using visual examination, superglue fuming, and visualization with RUVIS. Several latent prints were visualized with the RUVIS system and photographed. The resulting prints were searched in a federal AFIS system and identified to a suspected terrorist. In this case, the RUVIS system produced clear, high quality latent prints with excellent contrast. Without the use of the RUVIS system, the perpetrator of this terror attack may never have been identified.

9.7 Chapter Summary

Visual examination is the first step for processing evidence. Oblique lighting—light shone at a shallow angle—creates contrast with light and shadow. Light travels in waves. A shorter wavelength of light is higher in energy than a longer wavelength of light. Light energy with wavelengths between 390 nm and 700 nm is visible as color to the human eye. Fluorescence is the light emitted when material is illuminated by a certain wavelength. Fluorescent materials glow only when energy (such as a forensic light source or laser) is applied. Fluorescence is viewed with special colored glasses and filters. Yellow filters are used with blue light. Orange glasses are used with blue/green light. Red glasses are used with green light. Fluorescent dye stains adhere to superglue and give fingerprints greater contrast under fluorescent light sources. Superglue fingerprints can be viewed with a RUVIS.

9.8 Review Questions

1. Why is it necessary to visually inspect any surface before processing it for fingerprints?
2. What is the best tool for examining a surface with oblique lighting?
3. What is color?
4. What is fluorescence?
5. Name three fluorescent compounds used in latent print processing.
6. True or false: Light from a forensic light source passes through a barrier filter.
7. Which color barrier filters (or safety glasses) are used in conjunction with the following colors of incident light?
    a. Blue light
    b. Blue/green light
    c. Green light
8. What does ALS stand for?
9. What type of light is used with the RUVIS? What color filter is used?
10. How does the RUVIS work?

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Physical Processing Methods

10

LEARNING OBJECTIVES

- Describe the components of fingerprint powders.
- Describe five types of fingerprint powders and their applications.
- Understand the procedure for processing dry, nonporous surfaces at crime scenes.

10.1 Fingerprint Powders

Fingerprint powders are a fast, effective, and low-cost method of latent print development. Fingerprint powders are used on dry, nonporous surfaces. The powder particles adhere to the oil and water constituents of latent print residue. They are most often used at crime scenes where large areas and fixed objects such as furniture, windows, and railings must be processed efficiently on-scene (Figure 10.1). Although "dusting for prints" is a common technique, it is also the least sensitive technique available to the fingerprint analyst when compared with chemical processing methods. For this reason, powder processing is not recommended for items that can be safely transported to a laboratory for chemical processing in a controlled environment.

Fingerprint powders are most effective on fresh fingerprints. The longer a latent print remains on a surface, the drier it becomes as the water evaporates. Even though the oils are still present, there is less material for the powder to adhere to. Regardless of its insensitivity as a technique, fingerprints recovered with fingerprint powder account for about 50% of the 60,000 fingerprint identifications each year in the United Kingdom.[1]

10.2 The Composition of Fingerprint Powders

Fingerprint powders were first developed experimentally in the nineteenth century.[2] The first fingerprint powders were composed of ground chalk and mercury.[2] Mercury was a common ingredient through the 1980s.[3] Lead was found in gray powders through the 1990s in concentrations reaching 40% or more.[3] While the formulations of fingerprint powders have changed throughout the years to address health and safety concerns, a majority of the fingerprint powders we use today were developed by the mid-1900s.[1,4]

Most nonmagnetic fingerprint powders are composed of a pigment and an adhesive carrier particle and/or a filler material.[5,6] The adhesive component is often a rosin extract, such as dragon's blood (powdered rosin of the *Daemonorops draco* plant), stearic acid, cornstarch, raven powder, *Acacia* powder, or *Lycopodium* powder.[1,5,7] *Lycopodium* powder is derived from the spores of the stag's horn club moss or Christmas tree fern (*Lycopodium clavatum*). The *Lycopodium* spores that form the powder are fine in texture, extremely

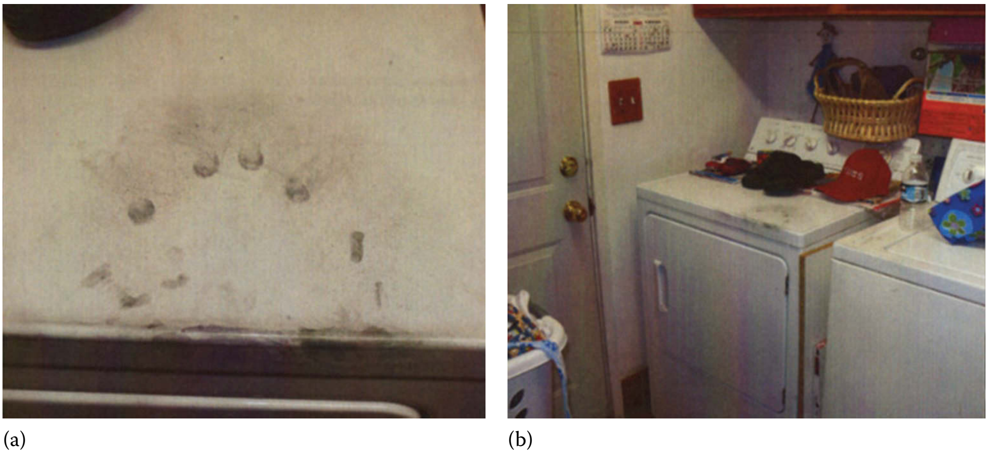

(a) (b)

Figure 10.1 Black powdered fingerprints (right) developed on a clothing dryer (left) at a burglary crime scene.

lightweight, smooth, and round.[1,5,8] The spores do not stick together in powder form. Stearic acid is a hydrophobic fatty acid. Its prevalence and hydrophobic qualities make it another suitable adhesive component for fingerprint powders. *Acacia* powder, also known as gum arabic, is a nontoxic adhesive.[9] It is commonly used as a food binder.[9] Similarly to stearic acid, it is a hydrophobic binder in any oil/water interface.[9,10] Raven powder is a fine carrier powder also used in a wide range of industries. It is found in historic homeopathic literature and is commonly used as a fine powder lubricant on automobile parts and as a powder coating on latex gloves.

Fingerprint powders also contain filler materials, most commonly fine to medium mesh pumice. Pumice is a volcanic rock, rich in silica (SiO_2), with a crystalline structure similar to that of glass.[11] The SiO_2 forming the vesicles in solid pumice accounts for pumice's low density.[11] This makes it ideal as a lightweight filler material.[12] Pumice is used as an abrasive or as a lightweight filler in wall insulation, plaster, soil conditioner, filtration, beauty products, cement, ceramics, paint, rubber, electroplating, automotive finishing, leather finishing, lithography, and other industrial applications.[12,13] In fingerprint powder formulations, fine mesh pumice is used as lightweight, anticaking filler material and as a carrier particle for pigments and adhesive elements. As a component of fingerprint powders, these features ensure even dispersal of the powder over a surface.

There are many different colors and formulations of fingerprint powders. The powder you choose will depend on the condition, texture, and color of the substrate. Fingerprint powder should contrast with the color of the substrate in question. For most reflective, transparent, and light-colored surfaces, black fingerprint powder is sufficient. If the background is multicolored or dark, a light-colored or fluorescent powder should be used. There are six types of fingerprint powders described in this text:

- Granular powder (black, white, and bi-chromatic)
- Magnetic powder (black, bi-chromatic, and/or fluorescent)
- Fluorescent powder (many colors available)
- Metallic flake powder (aluminum, copper)

- Nanopowders
- Infrared powders

How well the powder adheres to the latent depends on the size and shape of the powder particles, the surface chemistry of the powder, the adhesive properties of the powder, and the condition of the latent print.

10.3 The Fingerprint Powder Process

Fingerprint powders are applied with fingerprint brushes. Brushes come in several styles and are made of natural or synthetic materials. Granular powders are typically applied with *fiberglass brushes* composed of thousands of bundles of soft glass fibers, each about 12 µm in diameter (Figure 10.2).[1] Other common brushes are made from polyester, animal hair (such as camel or squirrel), or feathers. Magnetic powders are applied with a special magnetic applicator.

Once the fingerprint is developed with fingerprint powder and a brush, it is photographed and lifted from the surface with adhesive fingerprint tape. *Fingerprint lift tape* is a transparent or frosted adhesive tape available in 1-, 2-, or 4-inch rolls. The wider tape rolls are for lifting simultaneous fingerprint impressions (more than one finger at a time) or palm print impressions (Figure 10.3). Fingerprint lift tape rolls are pressure-wound to eliminate bubbles that may obscure latent print features.

Another type of adhesive lift tape is known as a *hinge lifter*. Hinge lifters are clear, hinged polymer sheets precut to various sizes. One side of the hinged device is coated with an adhesive, while the other side is transparent, white or black in color. The hinge lifter is used to lift and seal powder prints quickly and easily. However, critical case data and sketches cannot be recorded on most hinge lifters.

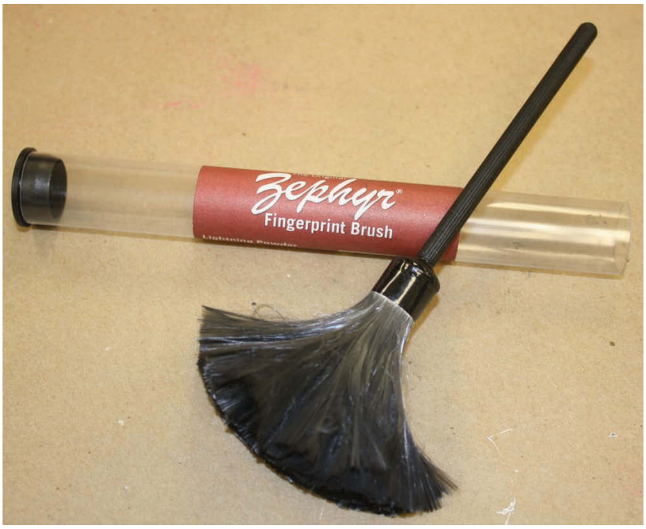


Figure 10.2 The Zephyr® Fingerprint Brush was developed in 1956 and is still used extensively at crime scenes today.

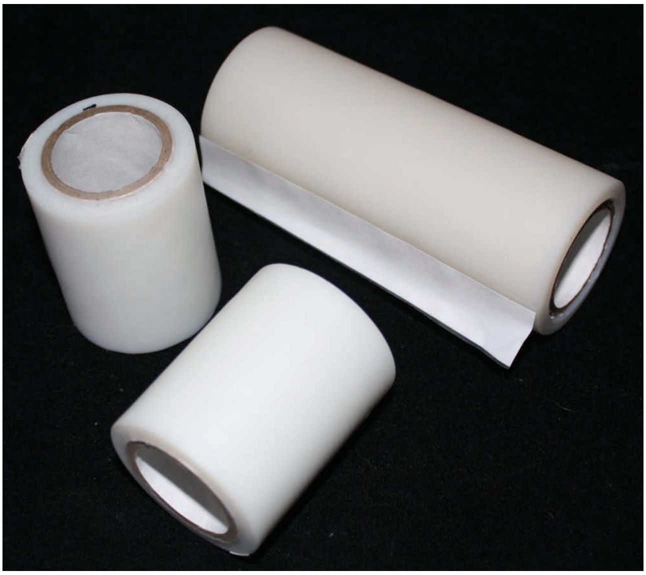


Figure 10.3 Rolls of frosted fingerprint lifting tape are available in 2″ and 4″ widths.

Latent prints can be found on a multitude of surfaces. Not all substrates are smooth and flat. Some surfaces are textured or curved, which makes lifting fingerprints difficult. Latent prints developed on textured or curved surfaces cannot be readily lifted with regular fingerprint lift tape or hinge lifters. Instead, it is possible to lift the developed latent print using silicone casting material or gelatin lifters.

The *silicone rubber lift material* is made up of a white casting material with the consistency of toothpaste and a catalyst (Figure 10.4). A catalyst is a chemical that initiates a

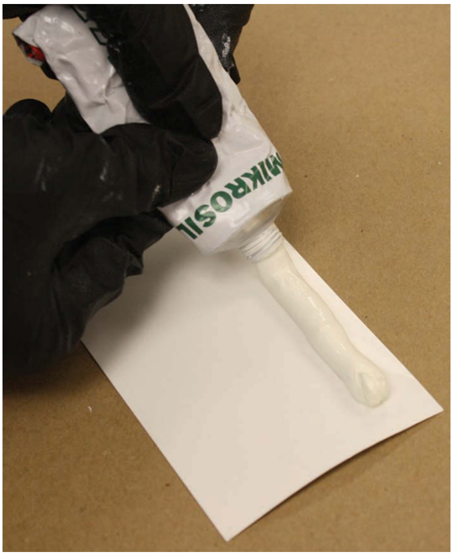


Figure 10.4 Mikrosil™ Casting Putty is a common silicone casting material used to lift powdered fingerprints from curved or textured surfaces.

reaction. In this case, the catalyst causes the white material to harden. The casting material is mixed with the catalyst and applied gently over a latent print that has been developed with fingerprint powder (Figure 10.5). After a few minutes, it hardens into a flexible rubbery cast similar in texture to Silly Putty™. The lift material can then be peeled from the surface (Figure 10.6).

Gelatin lifters are adhesive rolls or flat sheets with a layer of gelatin that makes them thicker and more pliable than fingerprint lift tape. After a latent print is developed on a surface with fingerprint powder, a gelatin lifter is applied and pressed into surfaces that are textured or curved. A rubber roller can be used to roll out air bubbles while the gelatin lifter is pressed onto the surface. Gelatin lifters are also used to lift shoeprints, dust patterns, and trace evidence.

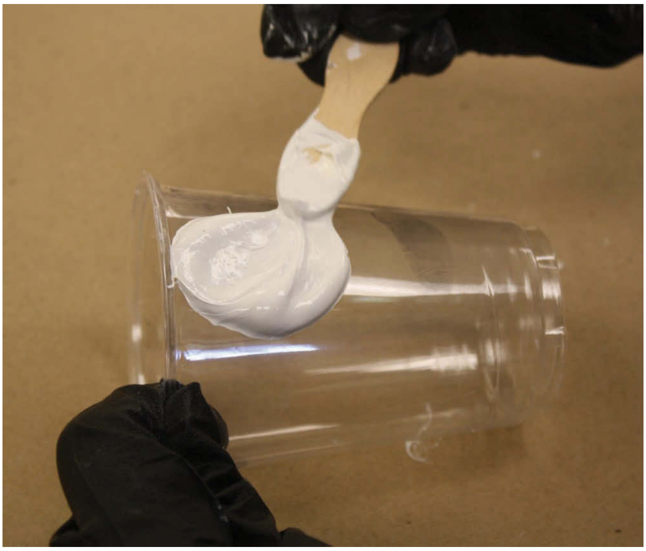
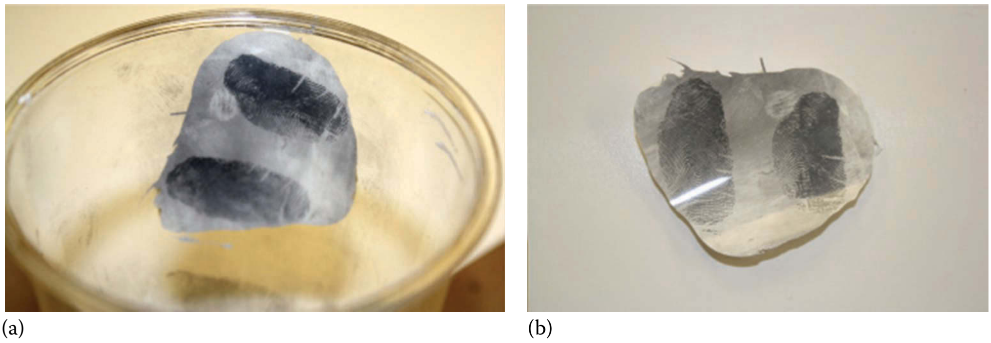


Figure 10.5 Silicone casting material is mixed thoroughly with a hardener catalyst and spread over a powdered fingerprint.



(a) (b)

Figure 10.6 After the silicone casting material hardens (left), it is removed from the surface (right).

Latent prints lifted with fingerprint lift tape are typically mounted onto *latent lift cards*. Latent lift cards not only preserve the print but also allow for documenting the print's original location on the substrate and other critical case information. Lift cards, also known as latent print backing cards, are glossy white or black on one side and have a nonglossy cardstock material on the reverse side (Figure 10.7). The reverse side of many commercially available latent lift cards is preprinted for filling out case information and sketching the surface with ease.

The color of latent lift card used is determined by the choice of fingerprint powder in order to maximize contrast. Black latent lift cards are used when latent prints are developed with white or light-colored powder. They are also used in conjunction with fluorescent powders. Standard white fingerprint cards are used when latent prints are developed with black powders.

The following procedure should be used to process dry, nonporous surfaces at crime scenes with granular powders:

1. Visually inspect the surface of interest with oblique white light.
2. Photograph any visible prints in situ (in place).
3. Pick a fingerprint powder color that contrasts with the surface.
4. Put a light layer of fingerprint powder onto a fingerprint brush and shake off the excess.
5. Lightly pass the brush over the surface until latent prints are visualized.
6. Photograph the visible latent prints.
7. Lift the latent prints onto a contrasting color of latent lift card using the appropriate lift tape for the surface.
8. Fill out all critical case information, complete a sketch, and note the "up" direction of the latent print (on both sides of the lift card) as shown in Figure 10.8.

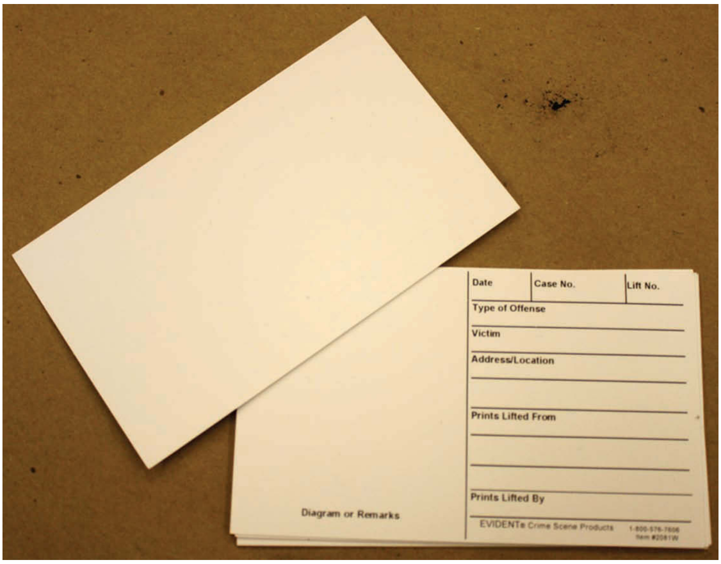
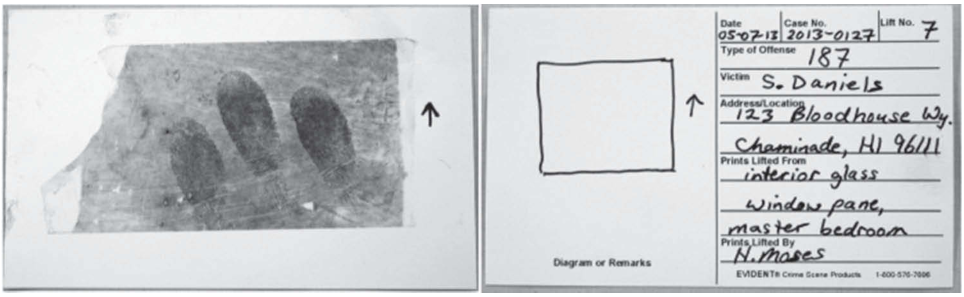


Figure 10.7 Latent lift cards.



Date 05-07-13
Case No. 2013-0127
Lift No. 7
Type of Offense 187
Victim S. Daniels
Address/Location 123 Bloodhouse Wy.
Chaminade, HI 96111
Prints Lifted From interior glass
window pane,
master bedroom
Prints Lifted By H. Moses

(a) (b)

Figure 10.8 Latent lift card front (left) and back (right) demonstrating directionality, case info, and sketch from the location where the latent print was developed.

10.4 Solid State Fingerprint Powders

Granular powders are composed of large asymmetrical particles. Black fingerprint powder is a carbon-based granular powder most commonly used in the United States at crime scenes. Black powder is used on light-colored surfaces such as windows, mirrors, light-colored cars, and highly lacquered woods (Figure 10.9). Black granular powder is applied with a fiberglass fingerprint brush and lifted with fingerprint tape onto white fingerprint lift cards or with hinge lifters.

Granular powders also come in several other colors, most commonly white, gray, and bi-chromatic. White and gray powders are insensitive and result in a significant amount of "background noise," which makes it difficult to distinguish the details of the print. *Bi-chromatic powder* (from "bi" meaning two and "chromatic" meaning color), also called *dual-contrast powder*, is a mixture of black granular powder and aluminum powder. This powder is especially useful on dark surfaces since the aluminum particles show up silver on the dark background (Figure 10.10). The prints are lifted with fingerprint tape onto standard white latent print cards.

Magnetic powder consists of particles that are smaller in size than granular powders. The black powder particles are blended with ferrous (iron-containing) particles that make

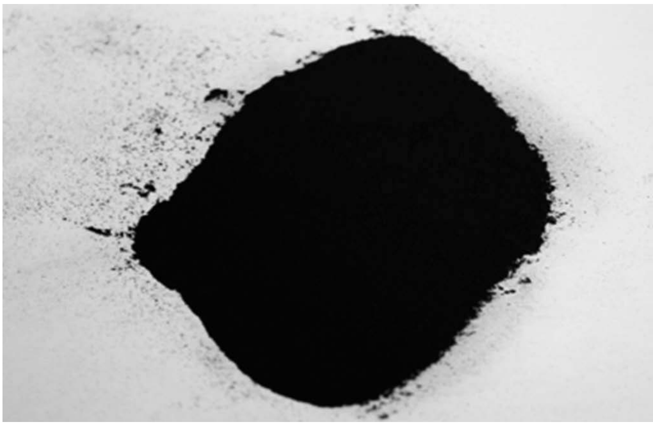


Figure 10.9 Black granular fingerprint powder.

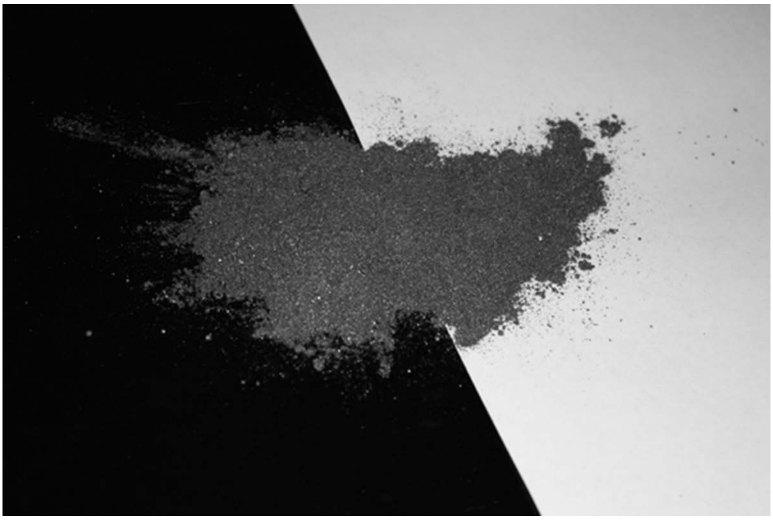


Figure 10.10 Bi-chromatic fingerprint powder.

the mixture magnetic. Magnetic powder is available in multiple colors and fluorescent formulations.

Magnetic powders are applied with a magnet-tipped applicator. The applicator, which often resembles a pen, is dipped into the magnetic powder. A "brush" of magnetic powder is formed on the end of the applicator, also referred to as a *magna brush*, magnetic wand, or magnetic brush (Figure 10.11). The powder is gently passed across the surface to develop the prints. To release the excess powder back into the container, the internal magnet is pulled up into the applicator, thereby releasing the powder (Figure 10.12). The empty wand

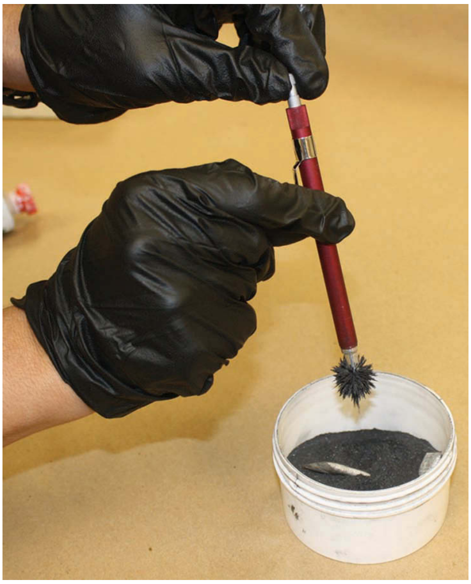


Figure 10.11 Magnetic fingerprint powder on the tip of a magna brush.

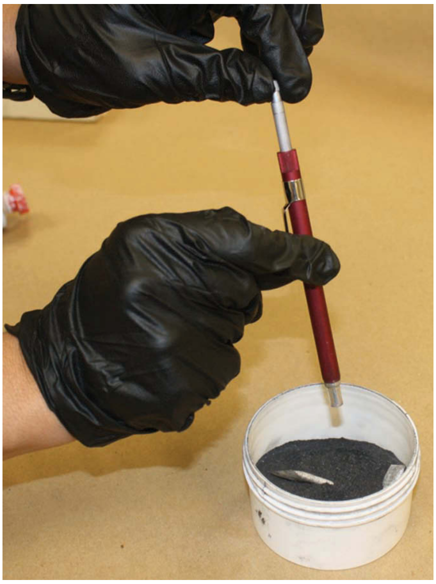


Figure 10.12 Pulling up the opposing end of the magna brush retracts the magnet in the magna brush and releases the magnetic fingerprint powder.

can then be used to "clean up" excess magnetic powder from the latent print and surrounding area. Latent prints developed with magnetic fingerprint powder are lifted with standard fingerprint lift tape, hinge lifters, gelatin lifters, or silicone rubber casting material.

There are many advantages to using magnetic powders. Due to the small size of the particles, magnetic powders are more sensitive than black granular powders, so they produce less background noise. Because the "brush" formed on the tip of the applicator is made of powder, there are no bristles that might inadvertently wipe away important details in the latent fingerprint. Fiberglass brushes cannot be used on greasy or dirty surfaces that might soil the brush, making it unusable in the future. Because magnetic applicators do not have brush tips, magnetic powders can be used on greasy surfaces such as fast-food cups, containers, and wrappers. Magnetic powders can also be used on Styrofoam™ (Figure 10.13). Magnetic powder is also cleaner to use than black granular powder because the unused or spilled powder can be gathered up with the magnetic applicator and returned to the original container.

There are some disadvantages to using magnetic fingerprint powder. For one, it cannot be used on large areas because of the limited surface area of the magnetic brush. It is also difficult to use on vertical or steeply angled surfaces because the powder on the end of the wand is pulled down by gravity. Black magnetic powders cannot be used on ferric metal surfaces (surfaces containing iron) because the magnetic particles will be attracted to the surface and will obliterate the fingerprint.

Fluorescent powders are minute fluorescent particles mixed with cornstarch or *Lycopodium* powder carrier particles. They are either granular or magnetic and are available in many colors including black, pink, red, orange, green, and yellow (Figure 10.14). The fluorescent components of these powders are solid forms of dyes such as Phloxine B, Rhodamine 6G, and fluorescein.[1,14,15] Fluorescent powders are a very sensitive fingerprint development method. They are useful for delicate dusting or on items that cannot get wet

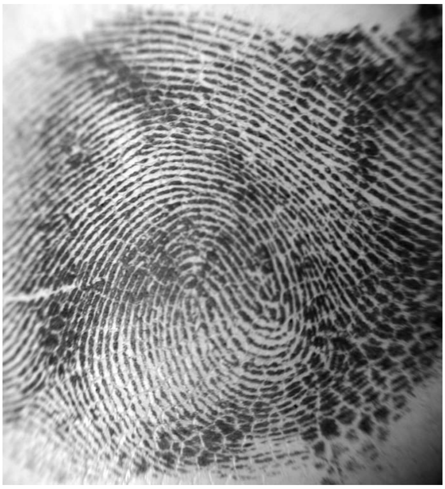


Figure 10.13 A fingerprint developed with black magnetic fingerprint powder on Styrofoam.

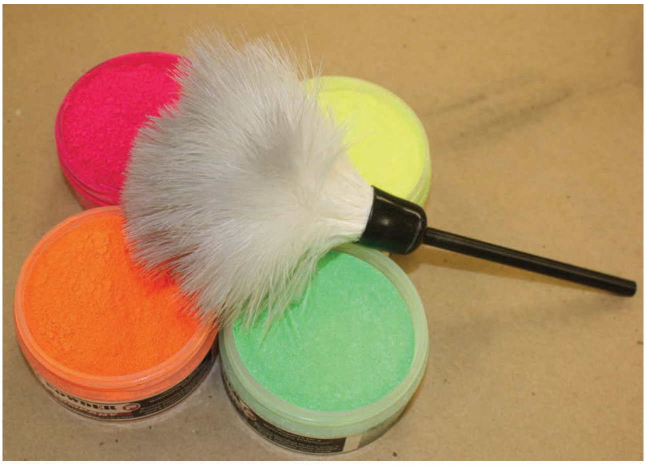


Figure 10.14 Fluorescent fingerprint powders of various colors with a feather duster applicator brush.

with chemical reagents such as computers, electronics, and cell phones. It is also used on surfaces that are multicolored and therefore do not provide contrast with any visible magnetic or granular powders.

Fluorescent powders glow under a specific wavelength of light, such as UV light or green light. Forensic light sources are used to visualize the fluorescent powder developed latent prints in a dark room using the appropriate colored filter or safety glasses. For example, orange fluorescent powder is visualized under green light (using an ALS or laser) with orange goggles. Fluorescent powders are used very sparingly with a feather duster brush (Figure 10.15). The powder is lightly applied to the surface, visualized, photographed, and lifted onto black fingerprint cards.

Metallic flake powders are composed of flattened flakes of aluminum, zinc, iron, or copper.[1,16] They are also available in magnetic form. Aluminum flake powder is most

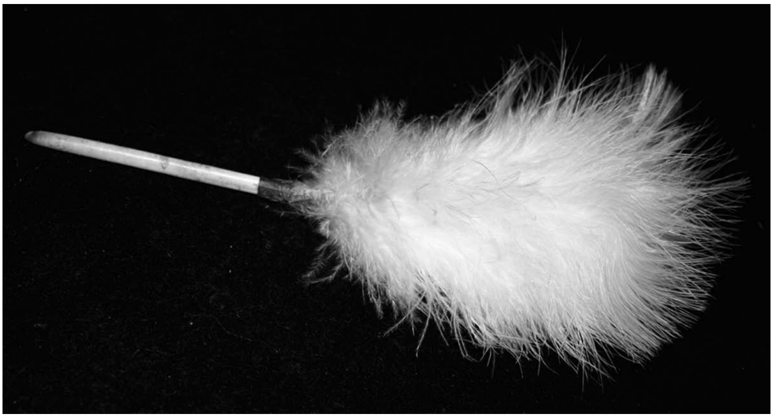


Figure 10.15 Feather duster fingerprint brush.

commonly used on smooth, dry surfaces. When a surface does not provide sufficient contrast with the aluminum flake powder, such as a silver vehicle, copper flake powder can be used. Metallic flake powders are the most commonly used powders in Europe.[16] Several researchers over four decades have determined that it is the most effective powder for fingerprint development because the flattened flakes are deposited in thin layers over the latent print and result in high-contrast prints with minimum background noise.[16–25]

Nanopowders and infrared powders are the newest classes of fingerprint powders. Nanopowder consists of minute spherical particles less than one micron in diameter.[26] The powder can be used in dry or aqueous (liquid) form, though the aqueous solution is more selective, and thus more effective.[26] Nanopowder shows promise as an emerging latent print development technique.

Infrared powders eliminate background interference from reflective, patterned, or colorful items as well as embedded reflective and fluorescent security features such as those on identification cards or bank notes. This has made infrared powders the development method of choice for modern polymer currency (especially in England, Canada, and Australia).[27] The infrared spectrum is between 700 and 1100 nm wavelengths.[27] As with common fingerprint powders, infrared fluorescent fingerprint powder adheres to a latent print on a surface. It is then visualized using an infrared light source. The infrared light is reflected by the surface but absorbed by the fingerprint.[27] The differences in absorption and reflectance create contrast and often appear as white fingerprints on a black background.[27] As with nanopowders, infrared powders are more sensitive in aqueous form.[27]

10.5 Aqueous Fingerprint Powders

Fingerprint powders are useful on most nonporous, dry surfaces; however, surfaces are often wetted by environmental exposure to rain or snow, or by condensation (such as with a recently opened soda can). Adhesive surfaces are also not conducive to solid-state fingerprint powders. Aqueous powder suspensions are used to develop latent prints on wet or adhesive surfaces.

Powder suspensions are mixtures of insoluble fine powder particles in a dilute detergent solution such as Triton X-100™ or Liquinox™.[1,25,28,29] The powder suspension is applied as

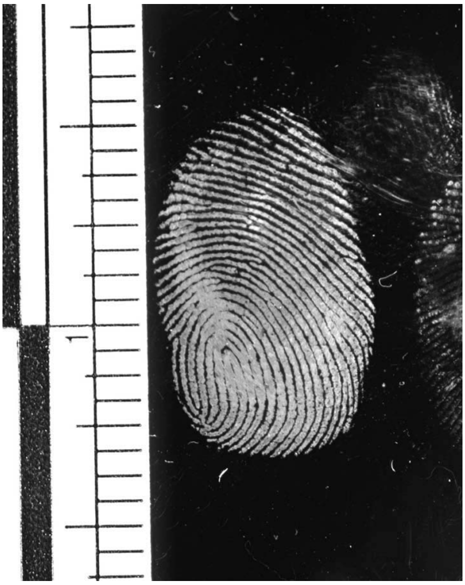


Figure 10.16 A fingerprint developed on black electrical tape with a white powder suspension.

a spray, painted, or dipped and rinsed with water. The powder particles selectively adhere to the sebaceous fingerprint residue, since the water-soluble components have been washed away.

A common powder suspension used at the crime scene is *small particle reagent (SPR)*. SPR is a formulation of molybdenum disulfide in water and detergent solution. It is available in a dark gray, white, or fluorescent formulation. SPR has proved successful in laboratory studies on wet vehicles, cardboard, metal, rusty metal, rocks, concrete, plastic, vinyl, wood, glass, and adhesive surfaces.[28]

Another type of powder suspension used commonly in fingerprint development is *adhesive-side powder*. There are several commercially available black and white powder suspensions (Figure 10.16). Each of these products is brushed, dipped, or sprayed onto the surface. Then the surface is rinsed with water. Fingerprint analyst can make their own powder suspensions in the laboratory with granular fingerprint powder, detergent, and water. More development methods for processing the adhesive side of the tape will be discussed in Chapter 13.

10.6 I Had a Case: Bar Brawl

Sometimes the location and orientation of latent prints is just as important as identifying the source of those prints. Documenting latent lifts at a crime scene with a detailed sketch, up arrows, and case information is therefore critical. In May of 2013, a bar fight broke out at a bar and resulted in a victim suffering head trauma. The victim had been hit over the head with a beer bottle. Crime scene investigators processed the bottles at the scene using black fingerprint powder. One bottle in particular had blood on its base, leading investigators to suspect it was the bottle used in the assault. Three simultaneous fingerprints were lifted from this bottle using black fingerprint powder, lift tape, and latent lift cards. The prints were documented as originating from the neck of the bottle.

The fingerprints were identified to a suspect, who insisted he had only drank from the bottle, not used it as a weapon. The directionality of the fingerprints, indicated by the sketch on the latent lift card, told a different story. The latent prints—the right index, middle, and ring finger of the subject's hand—were placed on the bottle in an upside-down position, rather than the normal position one would observe if an individual were drinking from the bottle. The upside-down configuration of latent prints indicated that he had wielded the bottle to use it as a weapon and provided an investigative lead for detectives.

10.7 Chapter Summary

Fingerprint powders are an efficient, low-cost method for developing latent prints on clean, dry nonporous surfaces. Because it is an insensitive technique, it should only be used at crime scenes on large areas or fixed objects. Fingerprint powder particles adhere to the water and oily components of the latent print residue. In addition to dry fingerprint powders, there are liquid powder suspensions available that are used to process wet surfaces and the adhesive side of tape.

There are six types of fingerprint powders: granular, magnetic, fluorescent, metallic, infrared, and nanopowders. Granular fingerprint powders, the least sensitive of the fingerprint powders, are brushed onto a surface with a fingerprint brush and collected with latent lift tape onto latent lift cards. Magnetic fingerprint powder is more sensitive than granular powder and is applied with a magnetic applicator. The resulting prints are lifted with tape, gelatin lifters, or casting material. Fluorescent powders are applied sparingly with a feather brush and lifted onto black fingerprint cards. Metallic aluminum fingerprint powder is the most effective of all the fingerprint powders. Nanopowders and infrared powders are recently developed methods that are sensitive and selective.

10.8 Review Questions

1. What is the first step in processing a surface with fingerprint powder?
2. What must be done before the powder-enhanced print is lifted?
3. What surface features should be taken into consideration before deciding what fingerprint powder and lifting method to use?
4. What are the advantages to magnetic fingerprint powder?
5. What are the disadvantages to magnetic fingerprint powder?
6. Which powder is most effective?
7. What lifting methods are used to lift powdered fingerprints from curved or rough surfaces?
8. What is bi-chromatic fingerprint powder? What is it used for?
9. How are fluorescent fingerprint powders visualized?
10. On what surfaces are fluorescent fingerprint powders used?

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Chemical Processing Methods
Porous Substrates
11

LEARNING OBJECTIVES

- Define and recognize porous substrates.
- Understand how fingerprint residues react when deposited on porous substrates.
- Describe the sequential processing method for porous substrates.
- Understand the reaction mechanisms and developmental results of treating porous items with ninhydrin, 1,8-diazafluoren-9-one (DFO), indanedione, and physical developer (PD).

11.1 Porous Substrates

In our daily lives, we are surrounded by and interact with both natural and synthetic objects of different sizes, shapes, colors, and materials. Any of these objects may have significance at a crime scene. Items of evidence may have a variety of properties. Each item has to be considered individually before it is processed for latent prints. One of the first things that must be determined is whether the item is porous or nonporous. Porous items are processed with a specific set of reagents and nonporous items are processed with a different set of reagents. Semiporous items are processed with a combination of porous and nonporous reagents.

Porous refers to a surface "containing pores" or small spaces within a substrate, for example, a sponge. Porous materials are permeable to liquids and gases. The most common porous substrates at crime scenes are paper, cardboard, and unfinished wood. Wood fibers are the basic raw materials for making paper. Wet pulp of mashed-up cellulose fibers from wood is mixed with fillers and dyes, pressed in screens to extract the water from the mash, dried, and cut into sheets. The overlapping cellulose matrix is a porous material, even though some commercial papers feel smooth to the touch.

Porous substrates absorb the latent print matrix. When latent prints are deposited on a porous surface, they permeate the fibers. The water-soluble components of the fingerprint residue (such as amino acids, sodium chloride, and urea) are absorbed into the surface, while the non-water-soluble components (such as lipids and waxy compounds) sit on the surface until they are wiped away or destroyed by environmental factors (Figure 11.1).[1] When the water evaporates, the other components remain embedded in the fibers. In a study of 15 paper samples, Almog et al. found that fingerprint residues do not penetrate into smoother (less-porous) papers as thoroughly as more porous papers.[2] They also found that deeper penetration of fingerprint residues results in higher quality processed prints.

Latent prints deposited on porous substrates are developed with chemical reagents. Amino acids—the building blocks of proteins—bind strongly to the cellulose fibers and

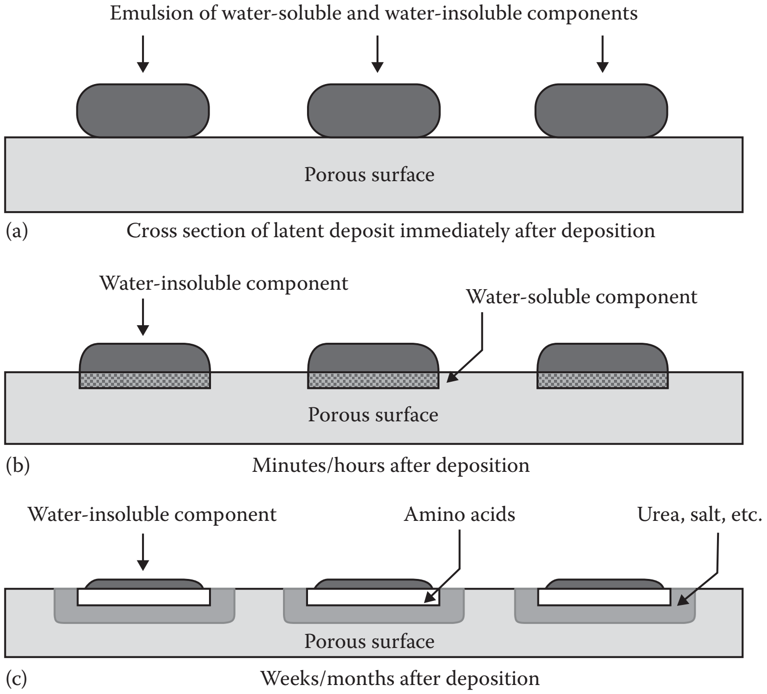

Emulsion of water-soluble and water-insoluble components
Porous surface
(a)
Cross section of latent deposit immediately after deposition
Water-insoluble component
Water-soluble component
Porous surface
(b)
Minutes/hours after deposition
Water-insoluble component
Amino acids
Urea, salt, etc.
Porous surface
(c)
Weeks/months after deposition

Figure 11.1 A cross section of friction ridge residue deposited on a porous substrate such as paper. When the fingerprint is deposited on the surface (a), the water-soluble components are absorbed into the substrate (b) and the water-insoluble components remain on the surface (c). (Reprinted with permission from Champod, C., *Fingerprints and Other Ridge Skin Impressions*. (Boca Raton: Taylor & Francis, 2004), (Figure 4.2).)

remain there unless the item gets wet.[3] Amino acids may be diluted or washed away if the item is exposed to excessive humidity or water. Most chemical reagents for porous materials react with amino acids, although reagents that react with the sodium chloride and lipid components are available. Aqueous fingerprint reagents are applied to the porous item by dipping or spraying so the reagent can penetrate the fibers (Figure 11.2). With

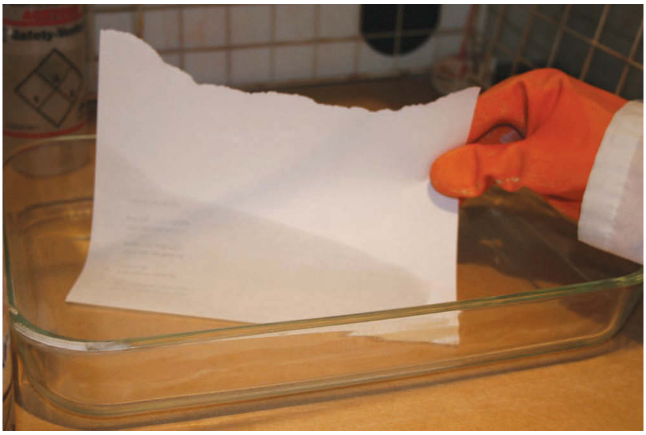


Figure 11.2 A fingerprint analyst dips a sheet of paper in a Ninhydrin solution.

some reagents, invisible latent prints become visible. Other fingerprint reagents result in a fluorescent print. Fluorescent latent prints glow under an alternate light source or laser. Regardless of the reagents chosen, they must be applied in sequence to be successful.

11.2 Sequential Processing

Several chemical reagents are available for processing porous items. The choice of chemical reagent will depend on the situation and the condition of the item. What color is the item? Is the item now or has it ever been wetted? How porous is the item? The first step is to photograph any patent prints that are visible before processing the item with any fingerprint reagent. During the chemical development process, the fingerprint analyst should wear personal protective equipment such as a laboratory coat, laboratory goggles or protective glasses, and gloves.

Regardless of the chemicals used, they must be applied in a particular sequence in order to be effective (Appendix A). The application of the chemical reagents in sequence may reveal more fingerprints than each process alone. It may also enhance the quality of previously developed fingerprints. Because some reagents inhibit or decrease the effectiveness of other reagents, the processes chosen must be applied in a particular sequence in order to be effective. After each process, any fingerprints that are revealed are photographed before moving on to the next process. The following is the porous processing sequence proposed in this and other texts:

1. Visual examination
2. Indanedione
3. DFO
4. Ninhydrin
5. Physical developer (PD)

Prior to discussing the listed chemical reagents, historical chemical reagents are presented. Some of these reagents are still employed in case work in a limited number of jurisdictions.

11.3 Historical Chemical Reagents

This chapter will concentrate on the most effective chemical reagents available to date. However, there are several reagents that are infrequently employed but are still available to the fingerprint analyst. These historic processing methods include iodine fuming and silver nitrate staining.

Iodine fuming is a technique that has been used for over 150 years.[4] This process involves blowing air into a tube containing calcium chloride crystals and iodine crystals.[5] The iodine crystals warm and sublimate (change from a solid to a gas), and the vapor is blown across the substrate. It reacts with the fatty and oily components of latent prints. The latent prints turn yellowish-brown in color. The colored product is not permanent unless it is fixed with iodine-fixing solution. It will fade over time. This makes it a useful process for clandestine operations.

Iodine vapors are toxic and corrosive. Accidental inhalation is possible, so great care must be taken when processing latent prints using this method. Iodine fuming may also be done in a fuming cabinet to negate this possibility. This is accomplished by suspending evidentiary items in a sealed fuming chamber. In the fuming chamber, iodine crystals are heated. The iodine sublimates—or turns from a solid into a gas—thereby creating the iodine fumes that develop the fingerprints.

Silver nitrate is a chemical reagent that has been used to develop fingerprints on porous items since 1877.[4,6] Silver nitrate ($AgNO_3$) reacts with the sodium chloride ($NaCl$) in the fingerprint deposits to form silver chloride ($AgCl$), which is a photosensitive compound. A photoreduction reaction converts the silver chloride to elemental silver.[3] A solution of 1%–10% silver nitrate in distilled water is applied to the paper by brushing or dipping. The item is air-dried and exposed to long-wave UV radiation or sunlight until dark-colored fingerprints appear. Fingerprints must be photographed immediately as the background will continue to develop as it is exposed to light, decreasing the contrast over time.[5] This reagent is not commonly used today due to its insensitivity, background staining, and tendency to degrade touch DNA.

There are many other chemicals used for fingerprint processing on porous surfaces. These include ninhydrin, indanedione, oil red O, DFO, and PD. The most common fingerprint reagents used today in forensic laboratories nationwide are ninhydrin, indanedione, DFO, and PD.

11.4 Ninhydrin

Ninhydrin was discovered by chance in 1910 by a chemist named Siegfried Ruhemann. Ninhydrin, also known as *triketohydrindene hydrate*, is both water-soluble and alcohol soluble. In solid form, it is a yellowish crystalline structure (Figure 11.3).[3] Ruhemann observed that the chemical reacts with proteins and amino acids to form a purple color, thereafter known as *Ruhemann's purple*.[3–5] It was originally used in chemistry to test for proteins in biological samples and to locate amino acids on chromatograms (snapshots of molecules separated via chromatography).[3] In 1954, a pair of chemists suggested that the aqueous solution of ninhydrin could be used to develop latent prints:

> In connexion with some recent legal proceedings, a new method for detecting fingerprints has been discovered by one of us (S.O.). The method involves the well-known Ninhydrin test for amino-acids, often used in chromatography. In this method, fingerprints on paper have always been considered a great nuisance, and one is often recommended to use forceps "to avoid fingerprints".[7] In our opinion, the new method will be most suitable for detecting fingerprints on paper and similar materials.[8]

Ninhydrin reacts with amino acids and other amine-containing compounds in fingerprint residues. Figure 11.4 demonstrates the mechanism for the reaction between ninhydrin and an amino acid. In this reaction, the nitrogen from the amino acid binds to the central ketone groups of two ninhydrin molecules, linking them in a complex.[3]

As the treated substrate develops, the amino acids and proteins in the latent print turn purple (Figure 11.5). Latent prints may be developed on paper long after they are deposited because amino acids are stable in paper fibers over time. In some instances, latent prints deposited on student notebooks were developed with ninhydrin 40 years after they were last handled.[6]

Figure 11.3 Ninhydrin crystals.

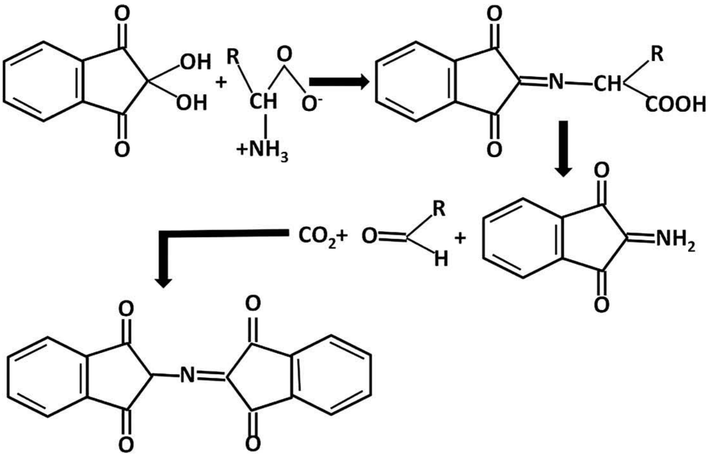


Figure 11.4 The mechanism for the reaction between Ninhydrin and an amino acid to form the purple compound Ruhmann's Purple.

Ninhydrin is applied in a fume hood. Porous evidentiary items are thoroughly saturated with ninhydrin by dipping, painting, or spraying the aqueous solution. Ninhydrin "recipes" all include a polar solvent and a carrier solvent (Appendix B).[1] Some contain acetic acid. The polar solvent is often ethanol or methanol, although methanol is a hazardous chemical.[1] Acetic acid is included in the solution because the reaction occurs more efficiently under slightly acidic conditions.[1]

The most current formulation of ninhydrin uses HFE 7100™ as an inflammable carrier solvent with low toxicity. HFE 7100™ (hydrofluoroether 1-methoxynonafluorobutane)

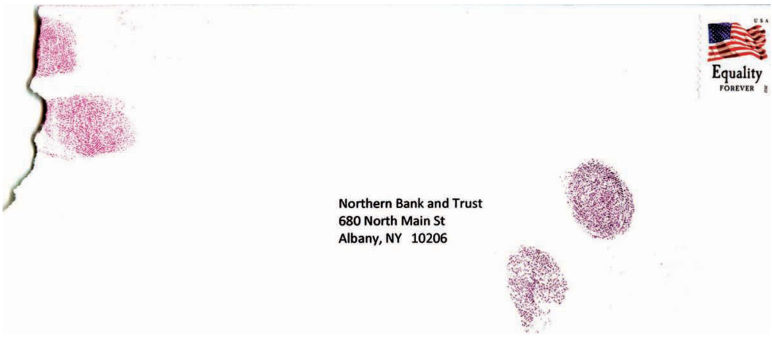


Figure 11.5 Fingerprints developed with Ninhydrin on a white envelope.

is supplied by the 3M™ company and may be purchased from most forensic supply companies.[9] HFE 7100™ has proven superior to previous carrier solvents because it does not cause ink to run. This is beneficial if questioned document analysis is warranted. In situations where the subject matter of the document is important—such as a suicide letter, threat letter, or forgery—the text must be preserved for the questioned document examiner. HFE 7100™ is an expensive reagent and can be cost prohibitive for many departments and agencies.

Once the porous item is treated with ninhydrin, it is air-dried at room temperature in a fume hood. The item should be left to develop for 24–48 h at room temperature for maximum development.[1] Heat and humidity speed up the development process, but excessive humidity may cause the fingerprints to "bleed." If this occurs, the ridges may appear indistinct rather than well defined. A clothing steam iron is sometimes used to steam the porous item, but this causes the background to be stained and the ridges to appear diffused and is not recommended. Background staining results in poor contrast between the developed fingerprints and the background. If the evidence must be developed immediately, the UK Home Office suggests developing the treated items at 80°F for 5–10 min at 65% relative humidity in an incubator.[10]

Ninhydrin fingerprints can be enhanced with metal salt treatments. A zinc nitrate solution will turn the purple ninhydrin fingerprints orange, while a cadmium nitrate solution will turn the ninhydrin fingerprints red.[1] The metallic elements form a complex with Ruhemann's purple. This complex not only results in a color change to enhance contrast in white light but also results in a luminescent compound that may be viewed under various light sources. The luminescence emission for the zinc nitrate treatment occurs at ~550 nm (green/yellow light).[1] The luminescence emission for the cadmium nitrate treatment occurs at ~590 nm (orange light).[1] These treatments are especially beneficial when ninhydrin alone results in a visible fingerprint with poor contrast. For example, a purple ninhydrin fingerprint on a blue, purple, or pink substrate is not as well defined as a fluorescent fingerprint that glows in contrast with a dark background.

Ninhydrin has been the workhorse for porous items in the forensic laboratory since the 1950s, and it still is today. It is likely that the popularity of ninhydrin is due to the fact that it results in a visible product that is relatively straightforward to photograph, scan, or photocopy. The fingerprints are generally of good quality and stable over time. There is also limited background noise observed.

Research in other chemical reagents for processing porous items for fingerprints focused on analogs of ninhydrin.[11,12] An *analog* is "a chemical compound that has a similar structure and similar chemical properties to those of another compound, but differs from it by a single element or a group."[6] Analogs are commonly developed in medical research laboratories to create drugs that either work better than the original drugs or work in a slightly different way. Examples of analogs are the antibiotics, such as penicillin and amoxicillin. Both antibiotics come from the mold *Penicillium*. Penicillin was historically used to treat most bacterial infections. Amoxicillin was developed from penicillin as an improved antibiotic.

Similarly, analogs of ninhydrin have shown promise as future latent print development reagents. Two of these analogs are 5-methoxyninhydrin (MN) and 5-methyl-thioninhydrin (MTN).[13] Both reagents result in latent prints that are visible and fluorescent. Neither reagent requires heat for development. Almog et al. reported that both the reagents were more sensitive than ninhydrin.[13] These analogs are also more affordable than ninhydrin and may prove to be more prevalent in the future.

Over time, many chemical reagents have been tested as possible fingerprint reagents. Most of these reagents are fluorescent in nature and are thus not readily seen with the naked eye. The most commonly used fluorescent fingerprint reagents for porous materials are DFO and indanedione.

11.5 DFO

Another chemical reagent commonly used in the forensics laboratory is *1,8-diazafluoren-9-one* (*DFO*). It was developed as a highly fluorescent fingerprint reagent in the 1980s.[6,10,14] Just like ninhydrin, DFO reacts with the amino acids in fingerprint residues. The reaction mechanism is similar to that of ninhydrin. Unlike ninhydrin, DFO produces a strong fluorescent reaction that is not readily seen with the naked eye (Figure 11.6). This makes it more challenging to photograph. Fluorescent fingerprints are also easier to see on multicolored or dark backgrounds where purple ninhydrin fingerprints may not be visible.

Just like the ninhydrin process, DFO is applied in a fume hood by thoroughly saturating the porous substrate by dipping, spraying, or painting. A formulation for DFO working solution using HFE7100™ as a carrier solvent is given in Appendix B. The item saturated with DFO is dried in a fume hood. It must then be heated in an incubator at 100°C for 20 min. The DFO process must be completed in a dry environment, unlike the ninhydrin process, which is enhanced by humid environments. The resulting fluorescent prints are viewed with a laser or an alternate light source set to 530–570 nm (green light). The items must be viewed through orange or red goggles and photographed with an orange or red barrier filter.

DFO has been shown to be a superior fingerprint reagent as compared with ninhydrin in multiple studies. In Great Britain, the Home Office Centre for Applied Science and Technology found that DFO developed 1.6 times as many prints as ninhydrin.[10] In some cases, it developed twice as many fingerprints as ninhydrin.[1,3,14–17] It was also shown that MN and MTN are comparable to DFO in fluorescence, but more visible in white light.[13] Instead of choosing one chemical over the other, fingerprint analysts can use both chemicals in sequence. DFO is always used before ninhydrin. One chemical may develop

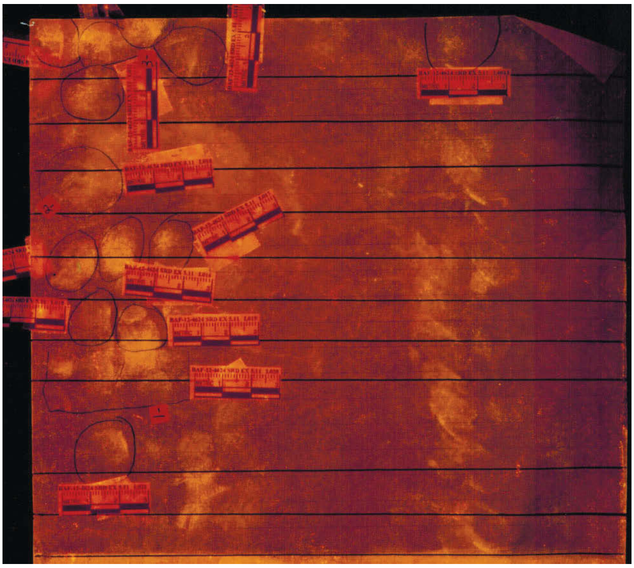


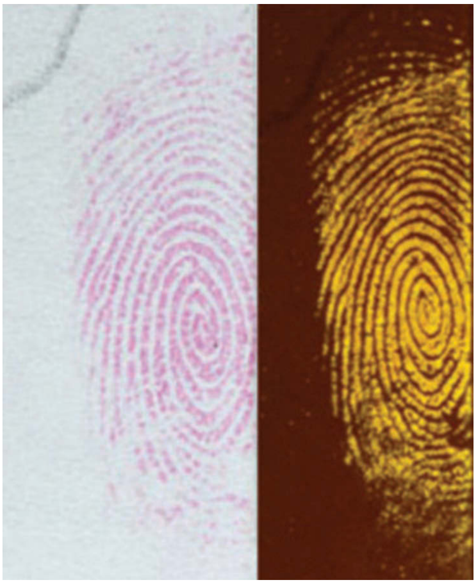
Figure 11.6 A DFO fingerprint developed on a printed document.

fingerprints, while the other may not. Conversely, both chemicals may develop the same print, but one may be clearer than the other. Even with the success of DFO, researchers continued to search for chemical reagents that developed better quality, higher contrast fingerprints. One of these porous fingerprint reagents, indanedione, is perhaps the most effective thus far.

11.6 1,2-Indanedione

Indanedione (*1,2-indanedione*) (indanedione–zinc) is a fingerprint reagent that is still emerging in forensic laboratories around the world. The reagent was developed in the mid- to late 1990s.[18–21] It has since been tested and improved over time by dozens of scientists and research groups.[18–26] Indanedione reacts with the amino acids in fingerprint residues, although it reacts with different amino acids from ninhydrin.[18,19] The fingerprints it produces are both visible (similar to ninhydrin fingerprints) and fluorescent (similar to DFO fingerprints) (Figure 11.7). The visible fingerprints are pink in color and are lighter than Ruhemann's purple. Liu et al. found that it successfully developed friction ridge detail on challenging surfaces such as stone, brick, cement, wood, and cotton.[22]

Indanedione (in its indanedione–zinc form) has been shown to develop latent prints on porous items better than DFO or ninhydrin alone.[18] It also performed better on its own than with DFO and ninhydrin in sequence.[25] It has been suggested that indanedione replace the current DFO–ninhydrin sequence, although many fingerprint analysts have simply added indanedione to the sequence. If used in sequence it is used first, followed by DFO and ninhydrin (Appendix A). One limitation to indanedione is that preliminary research suggests that it may degrade DNA. If DNA analysis is requested on a particular item, it must be done within 6 days of processing with indanedione.



(a) (b)

Figure 11.7 A fingerprint developed with Indanedione on paper is visible under white light (left) and fluorescent under green light from a forensic light source (right).

Similar to the ninhydrin and DFO processes, indanedione is applied in a fume hood by thoroughly saturating the paper by dipping, spraying, or painting. A common formulation for indanedione working solution using HFE7100™ as a carrier solvent is listed in Appendix B. The treated porous item is dried in a fume hood. Similar to DFO, items treated with indanedione must be incubated. The best results develop when the items are heated with a heat press set at 165°C for 10 s.[26] However, since most forensics laboratories do not have a heat press available, the dried items can be heated in an incubator at 100°C for 20 min at 60–80% relative humidity.[27] The processed items can be viewed with an alternate light source or laser set to ~520 nm (green light). The items must be viewed through orange or red goggles and photographed with an orange or red barrier filter. The indanedione process is effective and results in high-quality visible and fluorescent fingerprints.

11.7 Physical Developer

Amino acid reagents are relatively fast, easy, and sensitive processes for developing fingerprints on porous items. However, if the items have been wetted—through exposure to the elements, in kitchens or bathrooms, or in humid conditions—the water-soluble compounds in the fingerprint residue (such as amino acids) will dissipate. If there are no amino acids in the latent print, a different reagent must be used: one that reacts with the water-insoluble, sebaceous components of latent prints. These water-insoluble components often remain on the surface or slightly embedded in the porous substrate when other components have been washed away.

There are several reagents that have been tested over the years. The most common reagent is PD. Its name is a misnomer, as PD is not actually a physical process but a chemical one. PD is not only sensitive to lipids and oils in fingerprint residues, but it can also develop very old fingerprints. In one case, it developed 30-year-old latent prints and has even been reported to have developed latent prints remaining on a porous surface for over 50 years.[6,28]

PD is a fingerprint processing technique adapted from photographic development reagents. In a photo laboratory where photographs are developed by hand, the photo paper is placed in a tray with a chemical reagent and agitated, or gently rocked, until an image appears. PD is a similar technique. The item of evidence is gently agitated in a chemical reagent until dark gray or black fingerprints develop. It was first developed in the 1970s in the United Kingdom as a result of research contracted by the British Home Office through the Atomic Weapons Research Establishment.[1,28,29]

PD can be used in sequence with the amino acid reagents, but it must be used after treatment with amino acid reagents. The complete sequence is as follows: indanedione–zinc DFO, ninhydrin, and PD (Appendix B). However, if the item has been wetted, it is preferable to use PD on its own. If the item is wet when it is received, it does not have to be dried before the PD process is used.

Many different chemical formulations have been proposed over the years. Regardless of the method used, the complicated set of chemical processes results in silver metal deposits along the ridges of the latent fingerprints. The silver comes from a silver nitrate solution that is used to make the PD. All PD formulations have four steps: a presoak in an acidic solution, development in the PD working solution, a rinse in water followed by bleach solution, and a drying stage.

The first step is to soak the porous item in an acid: traditionally maleic acid. This acid has several functions. It removes the calcium carbonate from the paper to avoid creating nucleation sites for the silver particles.[29] The acid will also ensure that the pH of the solution does not become too basic and lower the acidity of the material.[29] The PD reaction works best in a neutral or slightly acidic environment. This minimizes the background staining and increases contrast between the gray/black fingerprints and the background.[10,28]

The second step in the process is to agitate the now acidic porous item in the PD working solution for 10 to 60 min, depending on how quickly and completely the fingerprints appear. The silver becomes deposited across the entire surface of the porous item, but adheres more strongly to latent print residues. The PD solution requires silver and iron ions in a slightly acidic buffer with a cationic surfactant.[1,28,29] A *cationic surfactant* is a detergent (soap) with a *hydrophilic* (water binding) head and a *hydrophobic* (lipid binding) tail. The surfactant is used to keep too much silver from being deposited on the substrate, creating excessive background interference. It accomplishes this by binding some of the silver in a *micelle* structure. In this micelle structure, the silver ions are bound in the center of a circular structure of alternating hydrophilic and hydrophobic ends (Figure 11.8).[1,5,29] The surfactant also stabilizes the solution to give it a longer shelf life.[29]

Three separate stock solutions are made separately. They are mixed together to form the PD working solution when it is needed. *Stock solutions* are the individual aqueous components of the reagent that must be mixed together to form a working solution. A *working solution* is the reagent used to develop the fingerprints.

The first stock solution is the redox solution, which acts as an oxidation–reduction agent. The second solution is the surfactant, or detergent, solution. Historically, the chemical Synperonic N was used as a non-ionic surfactant; however, it is no longer manufactured.

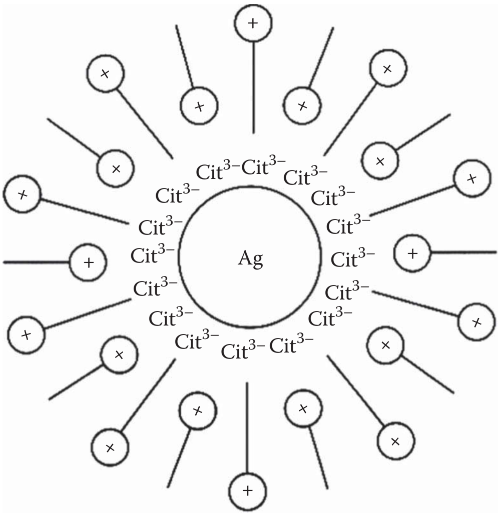


Figure 11.8 Cationic surfactant molecules with hydrophobic "tails" and hydrophilic "heads" (in the diagram the latter are represented by circles containing positive charges) surround a small amount of silver. The citrate ions surrounding the silver are absorbed during treatment with a citric acid solution. (Reprinted with permission from Cantu, A. and Johnson, J., Methods of Latent Fingerprint Development. In *Advances in Fingerprint Technology*, (Boca Raton: Taylor & Francis, 2001), (Figure 7.1).)

The United States Secret Service Laboratory has found that the detergent Tween 20 is an adequate replacement.[30] The third solution is the silver nitrate solution, which consists of 10 g silver nitrate and 50 mL distilled water. The final working solution is a mixture of all three stock solutions (Appendix B). The working solution should be prepared only when it is going to be used, as it has a shorter shelf life than each stock solution alone.

After the fingerprints are developed in the PD working solution, the porous item is either rinsed in water or immersed in a post-treatment of 1:1 household bleach to water. The bleach solution fades the background staining. If the background staining on the item is significant, bleaching is suggested. If the background staining is minimal, a water rinse should be sufficient. Finally, the item must be thoroughly dried.

While PD is effective, it is a cumbersome process that requires several processing steps and preparation of multiple reagents. The process takes up to an hour to complete after the reagents are prepared. Soaking the paper in an acidic solution weakens the paper, which may then tear easily. Also, the silver may be deposited in any creases, marks, or indentations on the evidence or in cracked or abraded glassware used to hold the working solution. Care must be taken to avoid creasing the porous item and to use clean, scratch-free glassware that has been rinsed in distilled water. The PD reagents are expensive. The process is also destructive as it permanently stains any surface with which it comes into contact, so it must be used after amino acid reagents. Because of these negative points, many forensic laboratories do not use PD as part of their regular processing sequence.

Oil red O is another fingerprint reagent that can be used to develop sebaceous latent prints on porous substrates. This reagent is discussed in Chapter 13. Regardless of the fingerprint reagents available, all of the reagents mentioned above must be used in the proper sequence in order to maximize the development of latent prints on porous substrates.

11.8 I Had a Case: Operation Pendennis

(Submitted by Rick Sinclair, Detective Senior Sergeant, Fingerprint Operations, Identification Services Branch, Forensic Services Group, New South Wales Police Force).

Since the 9/11 attacks on the World Trade Center in New York, city, state, and federal law enforcement agencies around the world have invested more resources to investigate "home-grown" terrorists. In July of 2004, a joint investigation into two suspected terror cells began in Sydney and Melbourne, Australia. The New South Wales Police, Victoria Police, Australian Federal Police, and Australian Security Intelligence Organisation initiated an extensive 16-month operation—Operation Pendennis—to gather intelligence and evidence against these terrorist cells, members of whom were loosely connected both with Al Qaeda and the Southeast Asian terrorist organization, Lashkar-e-Taiba.

The individuals under investigation had organized several terrorist training camps in the Australian Outback. They were in possession of beheading videos, weapons, ammunition, diagrams for building improvised explosive devices, electrical timers, circuitry, railway detonators, and jihadi propaganda. In addition to the intelligence and physical evidence, investigators of the Sydney cell developed a latent fingerprint on a bank deposit slip. The fingerprint, developed with indanedione, turned out to be critical forensic evidence linking a suspect to financial transactions in support of the cell's planning to commit a terrorist act in Sydney. Fingerprint evidence plays a critical role not only in local police investigations but also in homeland security operations worldwide.

11.9 Chapter Summary

Porous items are items that are permeable to liquids and gases. Examples of porous items include paper, cardboard, and raw wood. When fingerprints are deposited on a porous surface, they permeate the fibers. The water-soluble components of the fingerprint residue are absorbed into the surface, while the non-water-soluble components remain on the surface unless they are wiped away or destroyed by environmental factors.

Aqueous chemical reagents are applied to porous items in a particular sequence in order to develop both visible and fluorescent products. The most common chemical reagents that react with amino acids are indanedione, DFO, and ninhydrin. Indanedione must be used first. It produces visible pink-colored prints as well as highly fluorescent prints. DFO produces a fluorescent product. Ninhydrin is used after indanedione and/or DFO and produces highly visible purple prints. The most common chemical reagent that reacts with the sebaceous components of fingerprint residues is PD. PD must be used after the amino acid reagents in any sequence.

11.10 Review Questions

1. List five porous items you encounter in your daily life.
2. Why is it important to use the chemical reagents in a particular sequence?

3. Put the following reagents in order of how they should be used in sequence:
   a. DFO
   b. PD
   c. Ninhydrin
   d. Indanedione
4. Which reagents react with the amino acids in friction ridge residues?
5. What is the name of the colored dye product that results from a chemical reaction between ninhydrin and amino acids?
6. Why should ninhydrin-treated items be allowed to sit at room temperature to develop for 24–48 h even though the process can be sped up with heat and humidity?
7. Why are the fluorescent prints developed with DFO often preferable to the visible prints developed with ninhydrin?
8. How are DFO-processed prints developed and visualized?
9. How are latent prints developed and visualized using indanedione?
10. What are the four steps for processing a wet piece of paper for fingerprints using PD?

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Chemical Processing Methods
Nonporous Substrates
12

LEARNING OBJECTIVES

- Give examples of nonporous and semiporous items.
- Understand the sequential processes for nonporous substrates.
- Describe the vaporization and polymerization of cyanoacrylate.
- Describe the two most common methods of Superglue® processing.
- Describe the most common Superglue dye stains and the mechanism of their reaction with cyanoacrylate.
- Understand the vacuum metal deposition (VMD), multi metal deposition (MMD), and single metal deposition (SMD) processes.
- Describe the sequential processing methods for semiporous substrates.

12.1 Nonporous Substrates

Most of the objects we handle in our daily lives are manufactured from metal, plastic, and glass. These substrates are *nonporous*: not permeable to gases or liquids. Examples of nonporous items include cell phones, drinking glasses, plastic bags, and vehicle exteriors. When a fingerprint is deposited on a nonporous substrate, the matrix does not penetrate the surface as with porous substrates. Over time, the water component of the fingerprint residue evaporates, leaving behind the water-insoluble components (lipids, waxy compounds, etc.) and the components that do not evaporate with the water (amino acids, sodium chloride, urea, etc.).

Unlike prints on porous objects, the latent prints on nonporous objects remain on the surface (Figure 12.1). This makes them very fragile. Latent prints on nonporous objects can easily be obliterated if the items are handled improperly. Crime scene technicians must avoid handling any surfaces that may contain latent prints. Items that will be processed for latent prints should be handled sparingly. An item with heavily textured or rough surfaces can be handled on those surfaces since friction ridge detail is unlikely to be developed in those areas. For example, plastic bottles often have caps with ribbed edges around the circumference. If a plastic bottle is to be collected for evidentiary purposes, it can be lifted by the textured cap. Similarly, a handgun can be handled on the textured grip. If the item is completely smooth, it can be handled by the edges. It is important to take care when packaging nonporous items of evidence for the same reason. Latent prints may be rubbed off in transit by the action of paper evidence bags rubbing up against the item or if it is secured in a package that is too small.

The durability of latent fingerprints is affected not only by the actions of the people handling evidentiary items but also by environmental factors such as wind, rain, temperature, and humidity. Rain can obliterate latent prints. Wind and dry weather can dry prints quickly, as can exposure to direct sunlight. Leaves, dirt, or sand may blow across the

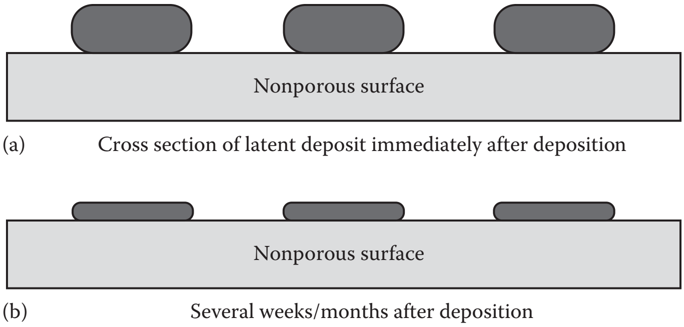
Nonporous surface
(a)
Cross section of latent deposit immediately after deposition
Nonporous surface
(b)
Several weeks/months after deposition

Figure 12.1 A cross-section of fingerprint residues deposited on a nonporous substrate such as glass. When the fingerprint is deposited on the surface (a), both the water soluble and water-insoluble components remain on the surface (b). (Reprinted with permission from Champod, C., *Fingerprints and Other Ridge Skin Impressions*. Boca Raton: Taylor & Francis, 2004, (Figure 4.3).)

surface, obliterating latent prints. A fingerprint in the shade in humid weather may survive much longer than a fingerprint in full sun in a desert environment. Fingerprint powders and powder suspensions such as small particle reagents (Chapter 10) are the traditional methods for developing fingerprints on nonporous surfaces. However, these processing methods are not as sensitive for detecting latent prints as chemical methods. Powders adhere to the oils and aqueous components of fingerprints. Fingerprint powders are used on fixed objects or large surfaces at crime scenes. Smaller items should be carefully collected, packaged, and submitted for latent print processing.

12.2 Sequential Processing

Chemical reagents are employed for processing nonporous items just as they are for processing porous items. In order to choose the appropriate reagent, fingerprint examiners must first analyze the substrate in question. What color is the item? Is the item fluorescent? Is the item now or has it ever been wetted? How porous is the item? Once the item is analyzed, the appropriate reagent is chosen and processing proceeds with a visual examination.

Similar to the chemicals used to process porous items, chemical reagents for nonporous items are applied in a particular sequence in order to be effective (Appendix A). Following each process, visible prints are photographed before moving on to the next process.

One of the most common methods for developing fingerprints on nonporous surfaces is Superglue® fuming. *Cyanoacrylate ester (CA)* is the chemical name for Superglue®. *Superglue® fuming* involves vaporizing CA in an enclosed chamber. This technique is always the first chemical process used to develop latent prints on nonporous items. The process “fixes” the latent print so that it can be further developed. The object is then treated with a dye stain that selectively adheres to the CA residue. The following is the general processing sequence proposed by this and other texts:

1. Visual examination
2. CA (Superglue®) fuming

3. Dye staining
4. Laser or alternate light source (ALS)
5. Fingerprint powder
6. Vacuum metal deposition (VMD)

These processes, along with several other common and emerging reagents and technologies, are described in detail below.

12.3 Cyanoacrylate Ester: Superglue® Fuming

Cyanoacrylate ester is known colloquially as Superglue®. In the 1970s, it was discovered that CA fumes—the vapors resulting from heating up Superglue®—cause latent fingerprints to turn white and become visible.[1,2] The Japanese National Police Agency developed this technique around the same time as it was examined in the United Kingdom.[3] In 1982, Ed German, a forensic scientist with the U.S. Army Criminal Investigation Laboratory in the Pacific (USACIL-Pacific), introduced the CA fuming technique to forensic science laboratories in the United States.[1–3] As with many other accidental discoveries, this breakthrough made an impact on the field of fingerprint analysis and changed the way forensic laboratories process evidence. CA fuming has become a routine process for fingerprint laboratories worldwide.

CA fumes selectively adhere to latent print residues. The result is white, 3D friction ridge impressions. The process effectively "glues" fingerprints to the surface of an object, making them more durable (although not indestructible). Extensive and continuing research has demonstrated that CA fuming develops fingerprints on any smooth nonporous surface, including the following common items: plastic bags, tape, plastic, Styrofoam™, carbon paper, firearms, metal, glass, coated papers, finished and painted wood, aluminum foil, cellophane, rubber bands, and smooth rocks.[1–3]

The mechanisms behind the CA fuming process are *vaporization* and *polymerization*. Vaporization is the conversion of a liquid into a gas. Polymerization occurs when individual molecules (called *monomers*) link to form a chain. The resulting long-chain molecule is called a *polymer*. In the case of CA fuming, a monomer of CA is attracted to the latent print residue. The CA monomer binds to the residue. Other monomers of CA bind to both the latent print residue and the CA monomer that has already attached. This mechanism results in a chain of CA molecules that form along the latent print impression, resulting in white ridges of polymerized CA. Figure 12.2 shows the polymerization reaction for CA resulting in a product known as *polycyanoacrylate*.[7]

The specific mechanism for these molecular interactions is still unclear. In order for the polymerization reaction to occur, the CA monomer needs something to react with

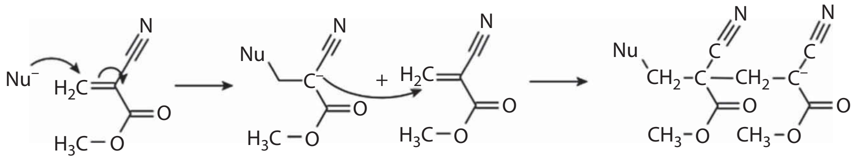

Figure 12.2 The CA polymerization reaction.

to initiate polymerization. This "initiator" is known as a *nucleophile*. A nucleophile is a molecule that donates electrons to form chemical bonds. Various components of the latent print residue have been suggested as initiators. Water molecules, amino acids, and sodium lactate can all act as nucleophiles, and all have been proposed by researchers as possible initiators of polymerization.[3,4] As of May 2018, research into this polymerization reaction continues.

Other variables that may affect the CA polymerization reaction include the temperature of the surface of the item and the environment, the humidity of the fuming chamber and the laboratory prior to processing, and the age of the latent print.[1–6] It has been suggested that low pH, high humidity, warm temperatures, and fresh latent prints are ideal settings for developing fingerprints using the CA fuming method.[1–6] Further research has shown that lowering the temperature of the substrate to ~8°C–10°C improves the polymerization process.[8]

There are many different methods for processing items of evidence with CA. The two most popular methods are the fuming chamber method and the vacuum chamber method. Both methods cause the liquid CA to vaporize, so that the fumes can interact with the latent print residues. In the CA fuming chamber, the liquid CA is heated until it vaporizes. In the vacuum chamber, a pump pulls air from the chamber to reduce the pressure, resulting in the immediate vaporization of the CA without heat.

A *fuming chamber* can be any container that can be sealed shut. The sealed chamber contains the fumes. A plastic box, fish tank, vehicle, or even Ziploc™ bag can act as a fuming chamber. Heating the CA requires a heat source, such as a mug warmer, hot plate, alcohol lamp, hair dryer, light bulb, or even the sun.[1] The Superglue® fuming process can work with a simple setup consisting of the items listed above (Figure 12.3); however, polymerization is more effective in a humid environment. The addition of a cup of hot water can simply serve to humidify the chamber. Improvised Superglue® chambers such as those listed above are still found in forensics laboratories and universities today as simple and inexpensive designs.

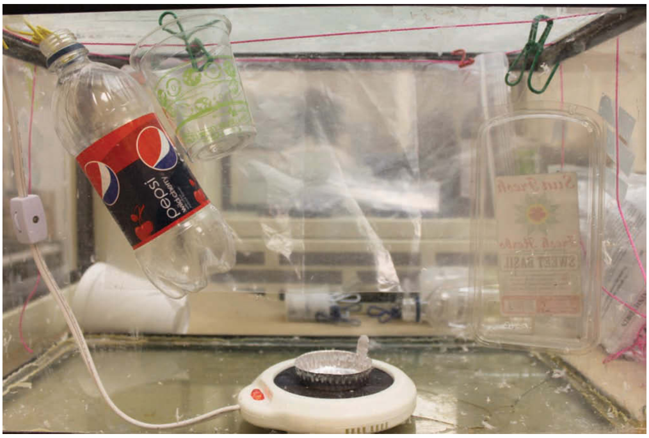

Figure 12.3 This photograph shows a CA fuming chamber constructed from a fish tank, Plexiglas lid, and mug warmer. The string and clips suspend the evidence to allow the vaporized CA to reach every surface.

Commercial fuming chambers are also available for purchase from forensic vendors (Figure 12.4). These chambers have many advantages over improvised versions. They contain built-in temperature-controlled heat sources. The temperature cannot be easily controlled with some heat sources such as light bulbs or hot plates. If the glue gets too hot (above 205°C–220°C), it can release toxic hydrogen cyanide gas.[3] Commercial equipment prevents the overheating of CA. Many of the commercial chambers also have internal fans to circulate the CA fumes throughout the chamber. This ensures even distribution of the vapors. Some also have built-in humidifiers or the option to attach an external humidifier in order to control the relative humidity inside the chamber. The ideal humidity for the polymerization process is 60%–80%.[3,4] Many commercial fuming chambers also have built-in fume hoods with special filters to evacuate all harmful fumes from the chamber at the end of the fuming cycle. The downside of these commercial units is that they are often prohibitively expensive for smaller forensic laboratories.

Regardless of the chamber and heat source used, the process is relatively straightforward. Evidentiary items are suspended or placed in the CA fuming chamber (Figure 12.5). If multiple items are fumed at the same time, there should be enough space between the items to allow the CA vapor to circulate. A source of humidity, such as a cup of hot water, is placed in the chamber. Several drops of CA (~0.5 g) are placed on an aluminum tray over a heating element (Figure 12.6).[7] The chamber is then sealed and the heating element is turned on. The items should be allowed to fume for 5 to 60 min. The time it takes to complete the process is dependent on many factors including the type of item, age of the print, humidity of the chamber, substrate, and size of the chamber.

Since the timing is critical for successful CA development, it is good practice to include a control sample with your evidentiary items. The control sample can be a glass slide or a black latent lift card with a fingerprint deliberately deposited on it. The control sample

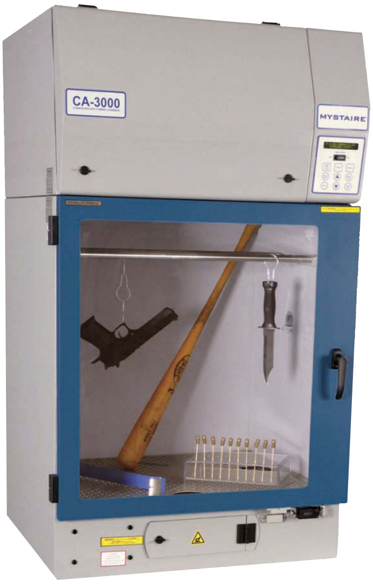

Figure 12.4 Mystaire® CA-3000 CA fuming chamber. (Reprinted with permission from Mystaire®.)

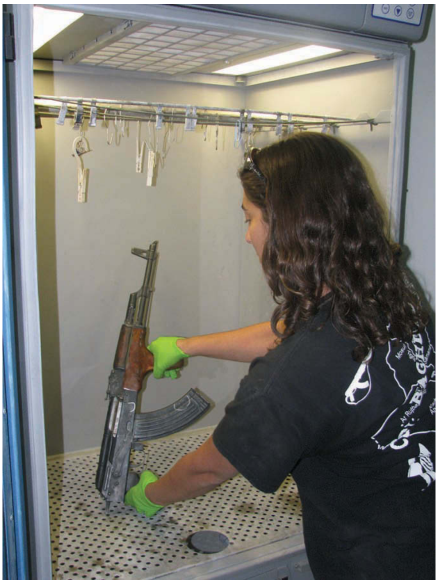

Figure 12.5 An AK-47 type rifle placed in the CA fuming chamber.

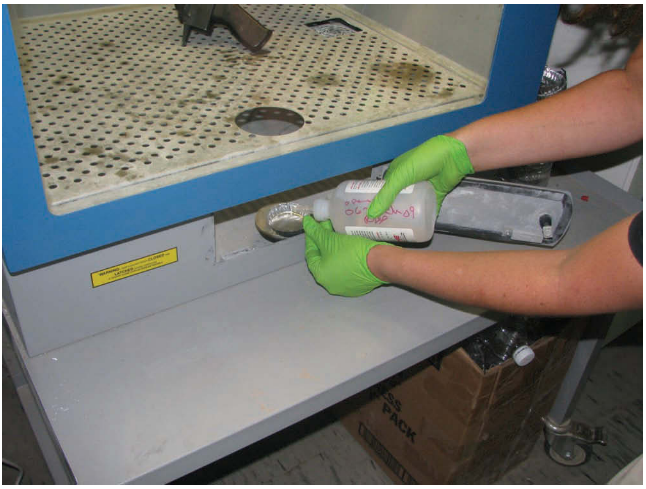

Figure 12.6 CA is added to an aluminum tray on the heating element of the fuming chamber.

should be similar to the type of evidence processed. When the fingerprint analyst begins to see white ridges developing on the control print, the process is complete (Figure 12.7). If the control sample does not show signs of development, it should be processed with a CA dye stain (Section 12.4). Often the developed latent prints are faint and not readily visible. Latent prints must be successfully developed on a control substrate before evidence is processed in any CA chamber.

The fingerprint analyst may not always see well-defined, white fingerprints on evidentiary items when they are removed from the fuming chamber. This is preferable to the alternative: over-processing the item. A reliability test should be performed prior to using

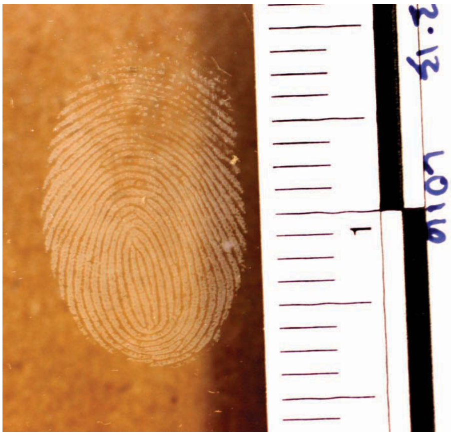

Figure 12.7 A latent print developed on a CD with cyanoacrylate fuming.

any fingerprint development process. Over-processing, or coating the substrate with CA, is a significant concern. Once the item is coated with CA, the glue cannot be removed. If the item is left in the chamber too long, the background and the furrows of the ridges will be coated with CA along with the friction ridges. This not only results in poor contrast between the friction ridges and the background but also causes the dye stain to adhere to the background as well as the latent print. The end result is an indistinct latent print with poor contrast.

There are other problems encountered when the fuming chamber is used. Watkin et al. state, "The path of the [cyanoacrylate] fumes produced cannot be controlled or predicted, sometimes resulting in uneven coverage of an exhibit."[9] They also emphasized the health and safety threat inherent with exposure to large amounts of CA fumes. Also, it is possible to have DNA contamination between evidentiary items fumed together in a fuming cabinet.[10] Research has also shown that DNA accumulates inside and outside a fuming chamber with use.[10]

Items processed in CA vacuum chambers do not have the same problem with over-fuming if an item is left in the chamber too long. They also utilize minimal amounts of CA vapor. A *vacuum chamber* is a thick metal chamber with a lid that creates a tight seal with a rubber O-ring (Figure 12.8). Heat is not used in the chamber. Instead, the glue is placed in the chamber on a metal tray or coated on foil to increase the surface area of the glue. The items of evidence are placed in the chamber and the lid is sealed. A vacuum pump evacuates air from the chamber, decreasing the atmospheric pressure to less than 1 torr.[2] One torr is equal to 0.001 atmospheres of pressure or 0.02 lbs/in^2. Reduced pressure causes the glue to vaporize quickly. The vapor is evenly dispersed throughout the chamber without the pressure of air filling space in the chamber. The pump is then turned off and the items are left to develop at room temperature in the reduced pressure environment. The items are left in the sealed chamber to fume for 20–30 min.

When an item of evidence is processed in a CA vacuum chamber, the resulting prints are often not white in appearance. They are usually faint, if visible at all. The polymerization process creates a thin coat of CA that is often translucent. Research has found that the vacuum fuming method is a superior process when latent prints are further developed with dye stain.[9]

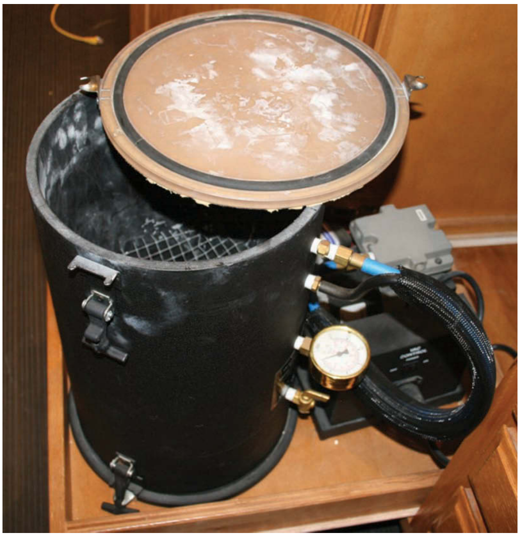

Figure 12.8 A CA vacuum chamber.

The drawbacks to vacuum fuming are that you cannot process wet items or items under pressure (such as unopened soda cans or bottles) in the chamber. Also, the equipment can be prohibitively expensive to purchase and maintain.

Besides the heat/humidity and vacuum fuming methods, devices such as fuming wands are also available. These were developed as portable units for use at crime scenes. The wand is a handheld device that generates heat with butane, similar to a cigarette lighter. A glue cartridge is attached to the tip of the device. As the wand heats up, the glue vaporizes and is expelled from the tip. The glue vapor is passed over an area of interest or an item of evidence. While this device is convenient and portable, it is not recommended. It is easy to overdevelop latent prints using this method. It is difficult to control the vapor. It also exposes the user to a significant amount of hazardous vapor.

Another method of CA fuming is the chemical acceleration method. This method can be used when a heat source is unavailable. The process involves soaking a cotton ball or cotton pad with sodium hydroxide (2 g NaOH in 100 mL H_2O).[1] The cotton is dried and stored in an airtight container such as a zip-top plastic bag. When chemical acceleration is necessary, a few drops of CA are applied to the dried cotton. This causes an exothermic (heat-producing) reaction that immediately vaporizes the CA.

This method of CA fuming can also be used to create vapors in a fuming chamber. Other methods of CA development are available, such as thin aluminum sheets coated with CA. These packets are peeled apart and used in vacuum chambers, cars, tents, or other enclosed areas. The thin layer of CA in these packets provides a greater surface area of CA for more efficient fuming in some circumstances.

Recall that optical, nondestructive methods such as a visual examination with white light, an ALS, laser, and/or reflective UV imaging system (RUVIS) should be completed prior to any chemical processing. Following a visual examination, CA fuming is always the first step in the nonporous chemical processing sequence regardless of the method, equipment, or initiation process used. However, the white or translucent CA fingerprints are not easy to see with the naked eye. Any visible prints should be photographed. They can also be examined and photographed using an RUVIS (Chapter 9). Following documentation, further processing is required to improve the contrast of the fingerprint.

12.4 Cyanoacrylate Dye Stains

Once an item is processed with CA, it is either treated immediately with a dye stain or left to sit overnight to allow the polymerization reaction time to set.[3] A dye stain is then applied to the item. This process is known as *dye staining*. *Luminescent* (glowing) dye stains selectively adhere to the CA polymer deposited along the friction ridges. The theory of dye staining is that "dye molecules get stuck in the polymer by filling voids in the compound."[3]

Dye stains are easy to use. They are prepared by dissolving the material in a solvent or mixture of solvents. A dye stain is applied to the substrate by spraying or dipping. The substrate can then be washed with an alcohol solvent or water to remove the excess dye from the surface and dried (Figure 12.9). The resulting *fluorescence* is viewed with an ALS, UV lamp, or laser depending on the dye stain selected. The light source shines a powerful beam of light set to a specific wavelength (color) onto the dye-stained item (Figure 12.10). This step is performed in a darkened room so the fluorescence can be visualized.

A *barrier filter* allows fluorescent fingerprints to be seen with the naked eye. It allows light of a certain wavelength range to be viewed and blocks the rest of the light. Barrier filters can be colored safety glasses, camera filters, or Plexiglas sheets (Figure 12.11). High contrast is observed with yellow or orange fingerprints "glowing" on a dark background. Different colors of light and barrier filters are recommended for different dye stains. Depending on the background color and luminescence of the items processed, items treated with the same dye stain may display different levels of contrast when viewed with different wavelengths of light.

There have been many dye stains proposed by researchers over the years. The most common dye stains used in forensic laboratories worldwide are discussed here: Rhodamine 6G (R6G), Ardrox, 7-(*p*-methoxybenzylamino)-4-nitrobenzene-2-oxa-1,3-diazole (MBD),

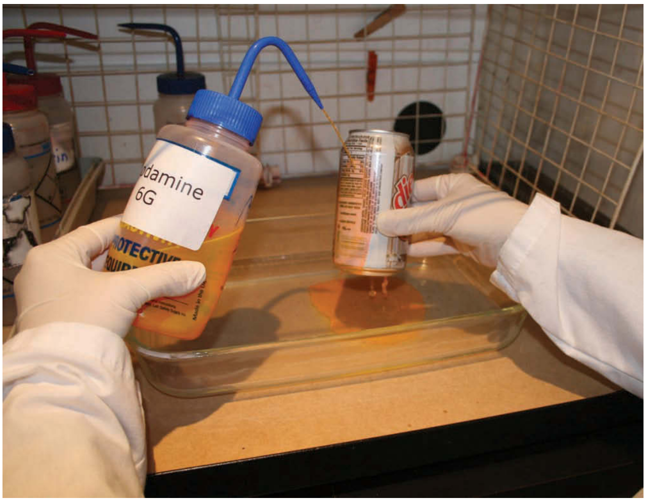

Figure 12.9 Application of Rhodamine 6G dye stain.

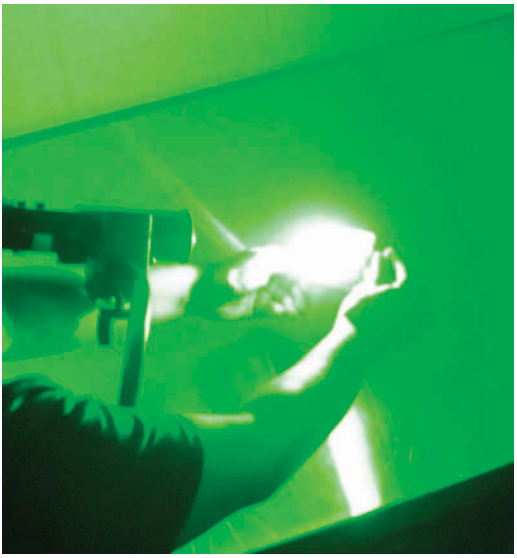

Figure 12.10 Monochromatic laser light viewed without a barrier filter.

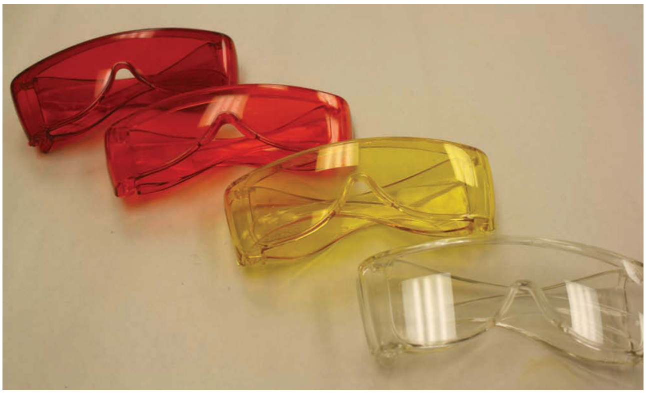

Figure 12.11 Colored safety glasses worn as barrier filters in conjunction with a forensic light source.

and basic yellow 40 (BY 40). Each dye stain is viewed under a specific colored light source (or a range of wavelengths). It is also possible to mix certain dyes to cause the latent prints to fluoresce over a wider range of wavelengths (and multiple light sources). The most popular dye mix is *RAM*, which is a combination of R6G, Ardrox, and MBD.

Some of the preferred dye stain working solutions are made using petroleum ether. Petroleum ether is a volatile, highly flammable nonpolar solvent and should be handled with great care. It is flammable when combined with strong oxidizers or when exposed to temperatures above its flashpoint. Some dye stain formulations include methanol, which is toxic. The Royal Canadian Mounted Police (RCMP) have had success with ethanol- and methanol-based formulations of R6G, Ardrox, and BY 40 (which they refer to as brilliant yellow 40) that do not include petroleum ether.[11]

R6G, also known as basic red 1, is arguably the most popular dye stain used in the United States. It was introduced in the early 1980s and has since become part of the CA

Figure 12.12 A working solution of Rhodamine 6G in methanol.

processing sequence.[5,12] There was some debate about whether or not the dye is carcinogenic, but research over several decades has produced mixed findings.[13] R6G is safe as long as it is handled properly.

R6G is a solid dark-green powder at room temperature. It is mixed with methanol to form a bright orange working solution (Figure 12.12, Appendix B). The CA fumed item is dipped or sprayed with R6G and rinsed with tap water or methanol. The item is then viewed with an ALS or laser under blue-green or green illumination. If the item is viewed under blue-green light (wavelengths between 490 and 515 nm), it is viewed using an orange barrier filter. If the item is viewed under green light (wavelengths between 515 and 550 nm), it is viewed using a red barrier filter. The fluorescent prints will appear orange in color against a dark background (Figure 12.13).

Ardrox was proposed as a strongly fluorescent alternative to R6G in the 1980s.[5] Original formulas included Freon 113 as a solvent, but research in the late 1990s demonstrated that a solvent of methyl ethyl ketone (MEK) was more economic.[14] The RCMP use a simplified formula of aqueous Ardrox solution in methanol (Appendix B).[11] CA-fumed prints treated with this dye stain vary in appearance from whitish-yellow to yellow to green when viewed under UV and blue light, depending on the solvent and light source used. Ardrox in MEK will appear green. Ardrox in methanol will appear yellow.[2] Ardrox-dyed prints are viewed under long-wave UV radiation (in the 365–380 nm range) with UV protective or yellow barrier filters. Like sunglasses, the UV protective glasses filter out harmful UV radiation that may damage the eyes. All exposed skin surfaces should be protected from both short- and long-wave UV radiation by wearing proper personal protective equipment at all times.

BY 40 is a nontoxic alternative, reported by Kent to be more effective than R6G and equivalent to Ardrox.[5] There are several suggested formulations of BY 40. The nontoxic ethanol formulation is presented in Appendix B. As its name suggests, fingerprints treated with BY 40 fluoresce yellow. Fluorescence is viewed under long-wave UV radiation around 365 nm using a UV protective or yellow barrier filter. It can also be viewed under blue-green light (450 nm) using an orange barrier filter.

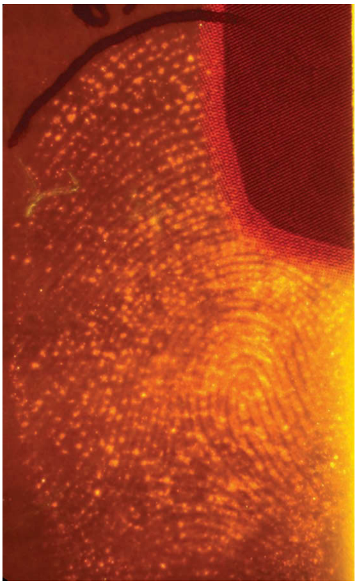

Figure 12.13 A fingerprint on a nonporous surface developed with CA fuming and Rhodamine 6G dye staining.

RAM is a mixture of several dye stains that can be viewed under a wide spectrum of colored illumination. It is a mixture of R6G, Ardrox, and a third dye stain called MBD. MBD is viewed under blue-green (~450 nm) or green light (515 nm) with an orange barrier filter. This dye stain mixture allows the examiner to view the item under UV, blue, and green light ranging from 365 to 550 nm. The proper UV, yellow, orange, and red barrier filters must be used with each range of wavelengths.

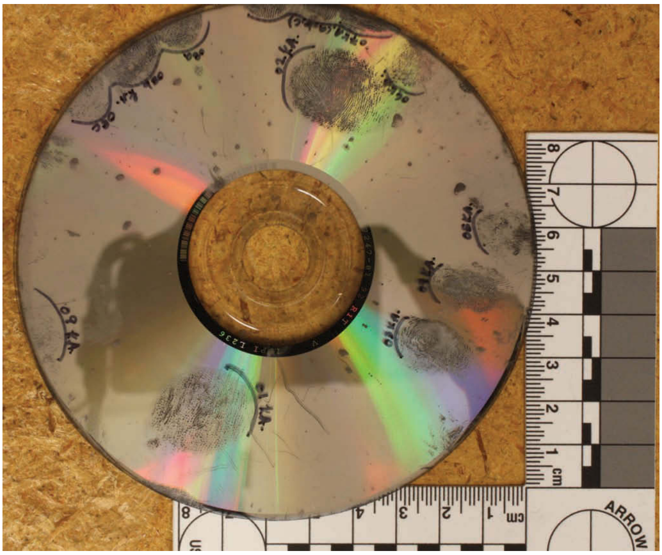

Figure 12.14 Fingerprints developed with black magnetic fingerprint powder after CA fuming and dye staining.

Regardless of the dye stain used, it cannot be used on the porous areas of semi-porous items because the substrate absorbs the reagent causing the background to fluoresce along with the prints. Dye stains are also not effective on objects that have fluorescent surfaces. There will be no contrast observed between the fingerprint and the background if the background is also "glowing." Instead, fingerprint powder such as black magnetic powder can be used on these surfaces. The powder is applied and lifted onto a latent lift card. Even if the item is nonporous, black magnetic fingerprint powder may be used after dye staining any fumed item as the final step in the sequential process (Figure 12.14).

12.5 One-Step Fluorescent Cyanoacrylate

Researchers have recently developed CA dye complexes that are mixtures of dye and CA. The resulting compound is a one-step fuming process that both fumes the print and dye stains it. The dye molecules are deposited during polymerization and can be immediately viewed with a forensic light source. Research into this process, as well as into novel dye stains, continues. One of these dye complexes, Lumicyano™, has been shown to result in prints with contrast better than or equal to R6G.[15] It has also been used successfully on challenging surfaces such as plastic bags.[16]

Processing items with a one-step CA-dye stain complex is similar to processing items with CA alone. Evidentiary items are placed in a superglue chamber. The powdered dye and specifically formulated glue are combined in an aluminum tray. The tray is placed on a hot plate where the glue vaporizes and polymerizes on the latent prints. If good contrast is not observed, items can be re-fumed a second time.

The one-step CA fuming and dye staining process saves time since the analyst does not have to treat the item with a separate dye stain. It can be used in any CA fuming chamber. Also, these methods have been shown to be compatible with subsequent DNA testing. One disadvantage of the technique is the current cost of the reagent.

12.6 Vacuum Metal Deposition

The process of VMD utilizes small amounts of metals vaporized in a vacuum chamber. The vaporized metals adhere to the surface of an evidentiary item everywhere except along the friction ridges (Figure 12.15).[6] In this way, it is the opposite reaction of CA fuming in a vacuum. In the CA process, the vapors adhere to the friction ridges. The VMD process creates what Champod calls "negative marks," although VMD can actually produce positive development in some situations.[7] The friction ridge impressions resulting from VMD processing are visible on the object because the background is coated with vaporized metal while the prints remain transparent. VMD has been utilized in the United Kingdom and several other countries since 1976 but has not been routinely employed in North America.[17]

VMD has successfully developed fingerprints on all types of surfaces including plastic, cloth, glass, and paper currency. It can be used alone or in sequence after CA fuming and dye staining. VMD was shown to be five times more effective at processing latent prints on

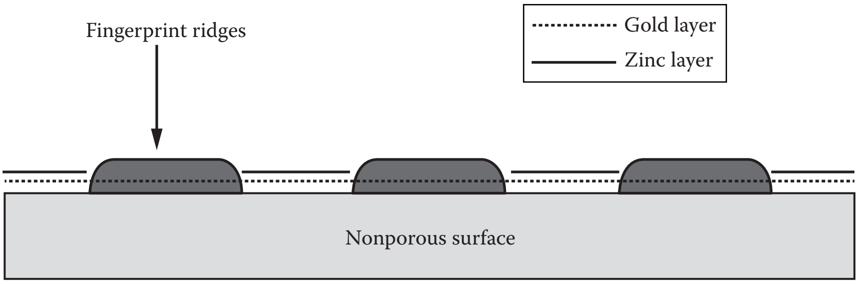

Figure 12.15 A schematic representation of gold and zinc deposition on a nonporous surface during the vacuum metal deposition process. (Reprinted with permission from Champod, C., *Fingerprints and Other Ridge Skin Impressions*. Boca Raton: Taylor & Francis, 2004, (Figure 4.45).)

fabrics than CA fuming.[18] It is a sensitive process that may be superior to CA fuming aged prints. Masters and DeHaan found that VMD is significantly superior to CA fuming when processing latent prints older than 2 years.[19] For fresh prints, CA fuming was equivalent to VMD.[17,19] It is often the only technique to successfully develop prints when other techniques have failed.

The VMD process involves alternately heating minute amounts of gold and zinc in a steel vacuum chamber (Figure 12.16). Similar to the CA vacuum chamber, the vacuum evacuates the air in the VMD chamber so the metal vapors do not have to compete with the air molecules. The item of evidence is placed in the chamber. Small amounts of gold (4–20 mg) and zinc (200 mg^{-3} g) are loaded into metal "boats."[17,19] The chamber is then sealed and evacuated to around 1×10^{-4} torr, depending on the manufacturer's specifications.[19] The gold is heated to 1,000°C for 15 s.[17,19] The vaporization occurs very quickly in a

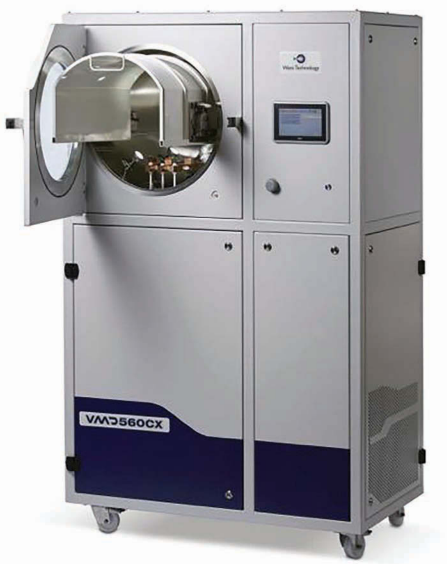

Figure 12.16 A VMD Chamber. (Reprinted with permission from GoEvidence Forensic Laboratories.)

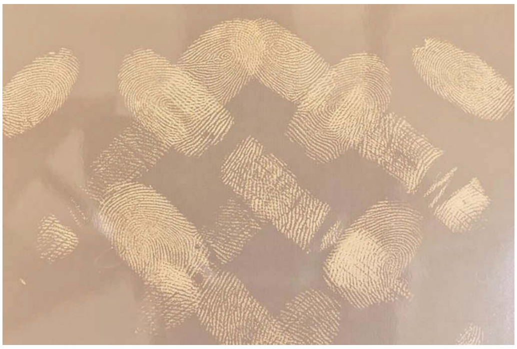

Figure 12.17 Fingerprints developed in a VMD chamber—aluminum on semi porous paper. (Reprinted with permission from GoEvidence Forensic Laboratories.)

vacuum. Zinc is then heated to 1,000°C. The zinc, which adheres to the gold, is allowed to vaporize until the surface is coated and the ridges become visible (Figure 12.17). The VMD chambers are prohibitively expensive for most forensics laboratories. Consequently, the equipment necessary for VMD processing is not readily available in a majority of agencies and private laboratories.

12.7 Multi Metal Deposition and Single Metal Deposition

MMD utilizes an aqueous colloidal gold solution rather than gold vapors.[20] The MMD process is completed in acidic conditions. Similar to VMD, the gold particles adhere to the substrate everywhere except on the latent prints. A second metal solution containing silver (PD, silver nitrate, etc.) results in silver particles adhering to the gold particles.[20] The background will appear gray in color.

As this method results in significant financial and time costs, SMD methods have been developed.[20,21] SMD relies on utilizing gold particles to enhance latent prints in a gold colloidal suspension.[20,21] This process eliminates a step and a reagent. Although these methods are extremely successful, they are not routinely used in most laboratories. Consequently, CA fuming coupled with dye staining is the most common method for processing latent prints on nonporous items.

12.8 Semiporous Substrates

Paper, cardboard, and wood are porous substrates. Plastic, glass, and metal are nonporous substrates. Some items are difficult to categorize as either porous or nonporous. These items are referred to as *semiporous* items. Semiporous surfaces absorb the water-soluble components of latent residues. The water insoluble (oily and waxy) components of fingerprints remain on the surface of the item.[1] Examples of semiporous items include magazines, waxy-coated paper products, carbon paper, photographs, glossy wall paints, wallpapers, latex gloves, and varnished woods.

Semiporous evidentiary items are processed for latent prints using a combination of porous and nonporous processing techniques. The following is a sample of a processing sequence that may be utilized for a semiporous evidentiary item:

- CA fuming
- Indanedione
- DFO
- Ninhydrin
- CA dye stain
- VMD

No matter what combination of processing methods is used, the sequence should first be tested on a similar surface before it is used on any item of evidence.

12.9 I Had a Case: CA Fuming a Vehicle

The interiors of vehicles contain various nonporous, smooth surfaces that are ideal for latent print processing. In California, a drive-by shooting resulted in three deceased victims at a city park. The vehicle in question was recovered and returned to the police department for latent print processing. The Crime Scene Investigator (CSI) decided to use CA fuming to process the interior of the vehicle.

A commercial product consisting of a thin layer of CA between foil sheets was used. The CA-coated foil was placed on the cloth seats of the car, CA side facing upwards. As it was a warm and sunny day, the CSI parked the vehicle outdoors. The investigator then closed the vehicle doors and windows and allowed it to fume in the warm sunlight. After approximately an hour, the CSI opened the doors to remove the superglue sheets and allow the fumes to ventilate.

Latent prints were developed on the seatbelt buckles and rearview mirror. The print on the mirror was subsequently identified to belong to one of the suspects in the drive-by shooting. This unconventional method of processing nonporous substrates resulted in a significant forensic contribution to a homicide investigation.

12.10 Chapter Summary

Metal, plastic, and glass are all examples of nonporous items. Powders can be used to process large, immovable objects at crime scenes but are not a sensitive processing technique. CA fuming fixes latent prints to a surface and develops 3D friction ridges. In a fuming chamber, heat and humidity cause the glue to vaporize and coat the latent prints in white polymer. In a vacuum chamber, the glue vaporizes in a vacuum, resulting in transparent CA prints. After visual examination, CA vaporization is the first reagent in the processing sequence.

The next step in the nonporous processing sequence is dye staining. Dye stains selectively adhere to the CA deposited on the friction ridges. Most dye stains are fluorescent and provide excellent contrast. The color and filter used to view the dyed substrate depend on the dye stain chosen. R6G, Ardrox, MBD, and BY 40 are the most common CA dye stains. Following dye staining, a nonporous item can be processed with fingerprint powders.

The final step in the nonporous processing sequence is VMD, although it is not routinely used in most forensic laboratories. Small amounts of gold and zinc are vaporized in a VMD chamber. The metal vapor coats the surface of the item everywhere except on the latent print deposits. VMD can be used on all types of semiporous and nonporous surfaces and has been successful in developing aged prints. MMD and SMD are alternatives to VMD.

Semiporous items do not easily fit into either the porous or nonporous processing sequences. A combination of processes is used to process these items.

12.11 Review Questions

1. List 10 nonporous items around you.
2. Put the following reagents in order of how they should be used in sequence.
   a. Magnetic powders
   b. Dye staining
   c. CA fuming
   d. VMD
3. How is the deposition of a latent print on a nonporous surface different from the deposition of a latent print on a porous surface?
4. What is the chemical name for Superglue®?
5. How do CA vapors develop latent prints?
6. How are latent fingerprints processed in a CA vacuum chamber different from latent fingerprints processed in a CA fuming chamber?
7. Why is it necessary to dye stain CA fumed prints?
8. What color/wavelength of light and barrier filters are used to view objects coated with the following dyes?
   a. R6G
   b. Ardrox
9. What color barrier filters are used for each of the following colors of light:
   a. UV radiation
   b. Purple (long-wave UV) and blue light (365–445 nm)
   c. Blue-green light (445–515 nm)
   d. Green light (515–550 nm)
10. What would be a logical sequence for developing latent fingerprints on a photograph?

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Chemical Processing Methods
Other Substrates and Matrices
13

LEARNING OBJECTIVES

- Describe the various methods for processing greasy latent prints, bloody impressions, latent prints on adhesive surfaces, latent prints on skin, and latent prints on metallic surfaces.
- Understand the challenges inherent in processing these types of latent prints and substrates.
- Understand the safety concerns inherent in processing bloody impressions, latent prints on skin, and latent prints on weapons.

13.1 Other Substrates

Fingerprint examiners frequently encounter challenging substrates or matrices composed of substances other than eccrine and sebaceous sweat. It is not uncommon to come across a greasy or bloody print. Metallic surfaces such as weapons and cartridge cases can be problematic. Some of the best quality latent prints are found on adhesive substrates such as tape, stamps, and labels. It is also possible to develop latent prints on human skin, although this has been much more successful in a laboratory than in practice in the field. When these challenging surfaces and matrices are encountered, specific chemical reagents and processes must be used in order to successfully visualize the friction ridge impressions.

As with the porous and nonporous substrates discussed in Chapters 11 and 12, the chemicals used to develop the items of interest depend on the surface on which the latent print is deposited as well as the composition of the latent print. The surface may be porous, nonporous, or semiporous and dark, patterned, or light in color. The latent prints may be fresh or aged. This chapter will cover some of the miscellaneous processes not covered in previous chapters, including methods for processing greasy prints and substrates, bloody prints, latent prints on adhesive surfaces, latent prints on skin, latent prints on metallic surfaces, and latent prints on thermal paper. All chemical processes should be completed in the laboratory under controlled conditions. During the chemical development process, the fingerprint examiner should wear personal protective equipment such as a laboratory coat, laboratory goggles or safety glasses, and gloves. All formulations and processing procedures are detailed in Appendix B.

13.2 Oily Prints and Greasy Substrates

Greasy or oily friction ridge impressions may be found on any surface. They are often patent or visible (Figure 13.1). The fingerprint analyst may also encounter surfaces that are contaminated with grease and therefore cannot be processed using common porous and nonporous chemical reagents. Oils are used in cooking, cosmetics, vehicle lubrication, and fuels. Oily fingerprints are commonly found on fast-food wrappers, bags, and cups; vehicles and garages; kitchen surfaces where greasy foods and cooking oils are used; and bathrooms, where cosmetics and lotions are often used. Fingerprint analysts cannot use standard fingerprint brush and black powder for these surfaces as the powder may clump on the greasy surface. The fingerprint brush can be ruined if it is contaminated with grease.

Oils are viscous, nonpolar substances composed of lipids or petroleum-based products such as grease, oil, or gasoline.[1] It is common to use chemical fingerprint reagents that react with these substances. These reagents form either a colored or fluorescent product. There are several processes to choose from when processing greasy fingerprints on nonporous surfaces: powder suspensions, cyanoacrylate fuming, natural yellow 3, Sudan black, and/or vacuum metal deposition.

The simplest process is to use a *powder suspension*. A powder of contrasting color (black for a light surface and white or fluorescent for a dark surface) is mixed with equal parts detergent and water. Painting the suspension onto the substrate with a camel hair or other delicate brush applies the powder suspension to the surface. The surface is then carefully rinsed and the visible fingerprints photographed. The process is repeated until the prints are clearly visible against the background.

There are also chemical reagents available for processing greasy or oily latent prints or substrates. *Natural yellow 3* is a fluorescent dye synthesized from the roots of the turmeric plant (*Curcuma longa*), a spice native to India and Indonesia.[2] It is also known as curcumin.[2] The dye is a natural plant derivative and a good choice of nontoxic reagent. Because it is fluorescent, it is the best choice for processing oily fingerprints on dark surfaces or latent prints on dark surfaces contaminated with grease.[3] The evidentiary item is dipped in the solution of Natural yellow 3 and rinsed with water (Appendix B). The

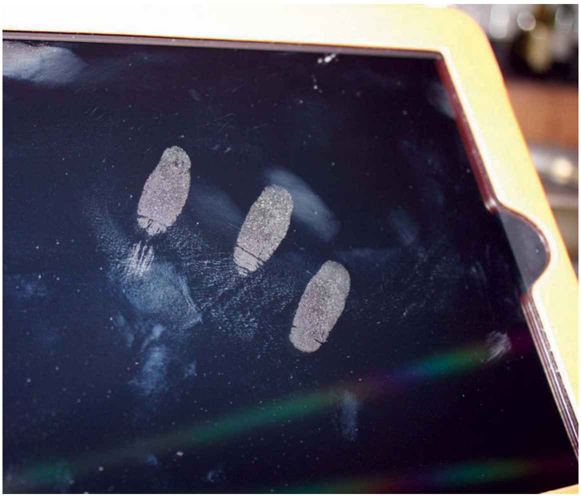


Figure 13.1 Greasy prints on a computer tablet screen.

fluorescent fingerprints are then viewed and photographed under blue and blue-green light with yellow goggles. Natural yellow is most effective on nonporous substrates.

Sudan black is the most commonly used fingerprint reagent worldwide for developing fingerprints on greasy nonporous or porous surfaces. It is also known as *solvent black 3*. Sudan black solution dyes oily fingerprints a dark blue or black color. It is therefore useful on light surfaces where the blue/black prints will be easily visible. Sudan black is also used to process latent prints on semiporous substrates such as latex gloves.[4] Items can be cyanoacrylate ester (CA) fumed prior to processing with Sudan black. The procedure involves dipping the item in the prepared solution for 2 min, followed by a water rinse (Appendix B).

Porous surfaces contaminated with grease or containing oily prints may be processed with *physical developer* or *oil red O*. Oil red O is a chemical reagent specifically formulated for greasy or oily substrates or prints on porous surfaces (Appendix B).[5] It is a fat-soluble dye that was first used to develop lip prints in 2002.[1] Oil red O is similar to Sudan black. Sudan black is preferable to oil red O because it is both more effective and it can be used on both porous and nonporous surfaces. Items processed with oil red O develop red prints on a light pink background.

Oil red O, similar to physical developer, can develop fingerprints on porous items that have been wetted or exposed to a humid environment. Oil red O has been shown to develop more latent prints on porous items than physical developer, except on brown paper bags or latent prints older than 4 weeks. Oil red O is also less damaging to the item than physical developer. It can be used in sequence with the previously mentioned porous processing techniques as follows:

- Indanedione
- DFO
- Ninhydrin
- Oil red O
- Physical developer

The final technique that may be used to develop oily fingerprints or fingerprints on greasy surfaces is *vacuum metal deposition* (*VMD*). As mentioned previously, VMD is a technique that is extremely effective for use on almost every surface and for aged fingerprints. It is, however, cost prohibitive and most forensic laboratories do not have the capability to perform this technique. Table 13.1 summarizes these processes.

Table 13.1 Reagents Effective for Processing Oily Prints and Latent Prints on Greasy Surfaces by Substrate Type

Substrate	Reagent(s)
Nonporous, dark, or patterned	Natural yellow 3, white powder suspension, VMD
Nonporous, light	Sudan black, VMD
Porous, dark, or patterned	1,2-indanedione, DFO
Porous, light	Oil red O, Sudan black

13.3 Blood

The human body contains one to two gallons of blood, depending on the individual's gender and size. Blood is composed mainly of plasma, white blood cells (leukocytes), and red blood cells (erythrocytes). Plasma is mostly water. White blood cells perform immune functions. Red blood cells contain *hemoglobin* bound to iron. The iron molecule from the red blood cell binds to oxygen, which is circulated throughout the body to oxygenate the body's cells. Hemoglobin makes up 95% of red blood cell's protein content. In order to process patent or latent blood prints, fingerprint analysts can use chemical reagents that react with proteins. These reagents dye the proteins, making them more visible or improving the contrast between the print and the substrate.[8]

Latent or patent friction ridge impressions in blood will almost certainly be encountered when processing violent crime scenes. The safety of the fingerprint analyst and other personnel must be addressed before attempting any of the processing methods described below. Blood may contain harmful *pathogens*, or diseases, such as hepatitis or HIV. Analysts must wear gloves at all times and label evidence bags as "biohazard" when they contain evidence contaminated with blood, to include bloody prints. Analysts should also wear a particulate mask in order to avoid inhalation of airborne blood particles. Protect clothing with a laboratory coat. If a crime scene contains a significant amount of blood, the analyst may choose to wear a Tyvek™ suit, booties, and safety glasses or goggles. Avoid accidental skin punctures and exposure by handling and packaging sharp items such as knives, broken glass, or hypodermic needles with great care. Always wash skin surfaces immediately after handling contaminated items, regardless of whether the skin came into contact with the items. Wash your hands immediately after removing gloves. Use biohazard disposal bags for gloves, bags, disposable equipment, protective clothing, and any other items that may have been contaminated. When the proper safety measures have been employed, you may start the processing procedures summarized below.

Latent or patent prints in blood can be used to identify the source of the fingerprint, but blood also has further investigative value. When one thinks of blood at a crime scene, one may initially think of its value as a source of DNA. However, DNA is not always a potent investigative tool. If the blood at the crime scene belongs to the victim, the source of the blood has little investigative value. Likewise, if the blood belongs to the suspect, but the suspect is both unknown and not found in the DNA database (known as the Combined DNA Index System [CODIS]), the DNA profile obtained is not probative.

Another issue to consider is the size of the fingerprint database versus the size of the DNA database. There are more than ten times as many fingerprints in Automated Fingerprint Identification Systems (AFIS) than there are DNA profiles. There are many reasons for this discrepancy. Fingerprints have been used as evidence for decades longer than DNA. Fingerprints were automated more than 10 years before DNA profiles were digitized. Perhaps the most significant difference is that DNA profiles, unlike fingerprint records, are not collected from all arrestees. Thus, there may be a higher probability of identifying a suspect if the fingerprint can be enhanced and identified.

However, one can never assume a bloodstain or bloody print belong to a suspect. The investigator must decide whether it is important to know the source of the fingerprint, the source of the blood, or both. Since techniques for modern DNA extraction, amplification, and analysis require very little blood; it is entirely possible to successfully examine both the fingerprint and the DNA. In a case such as this, latent or patent impressions that are of no value for fingerprint comparison purposes can be sampled with sterile swabs and submitted for DNA analysis. Prints that are of value for comparison purposes can be processed with fingerprint reagents, documented thoroughly through photography, and then sampled for DNA analysis.

Blood is visualized at crime scenes and in the laboratory for several different reasons. Presumptive tests are used to determine whether or not a substance is blood. These presumptive tests are mixtures of reagents that change color in the presence of blood, although false-positive results may occur. Chemical reagents may also be used to enhance latent, or invisible, bloodstains at a crime scene if the scene has been cleaned up or the bloodstains have been degraded. Insects such as blowflies, houseflies, and flesh flies may consume blood at crime scenes, removing any visible trace. Some common blood reagents result in either fluorescent or *chemiluminescent* products that glow under specific lighting conditions (Figure 13.2, Chapter 9). These reagents may demonstrate the locations of the suspect and victim during an assault via an analysis of the origin and directionality of the bloodstains.

Protein dyes are a class of chemicals that are used to visualize faint or latent bloodstains, including bloody latent prints. As mentioned earlier, friction ridge impressions in blood may be visible, difficult to see, or latent. It is often necessary to enhance the prints and photograph them. The fingerprints may then be compared to a known suspect or searched in an AFIS system. Items suspected to have bloody prints should not be CA fumed. The CA polymerization reaction can inhibit the blood reagents discussed in this chapter. However, bloody prints can be processed with fingerprint powder, although a disposable fingerprint brush must be used to avoid contamination of DNA of transmission of infectious diseases.

The most common protein dye used to enhance bloody fingerprints is *amido black*. It is also known as *acid black 1*. Amido black stains proteins a bluish-black color (Figure 13.3).[9] It has been used as a protein stain since the 1920s.[9] The original formulation of amido black working solution uses methanol as a solvent. Because methanol is highly flammable and toxic, water- and ethanol-based formulations were developed. These nontoxic formulations are well suited for use at crime scenes and are inexpensive alternatives to the traditional formulation (Appendix B). The methanol formulation works well on nonporous substrates. The water-based formulation can be used on both nonporous and porous substrates.

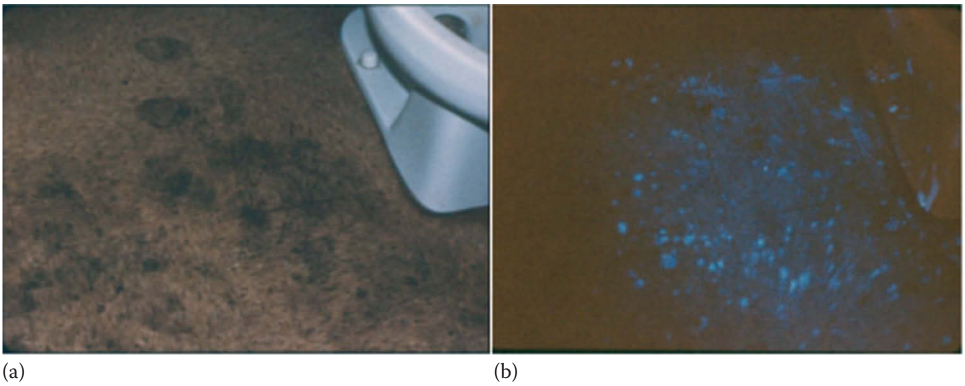


Figure 13.2 A bathroom floor at a crime scene before (left) and after (right) treatment with luminol. (Photographs courtesy of Wilson Sullivan, Chaminade University of Honolulu.)

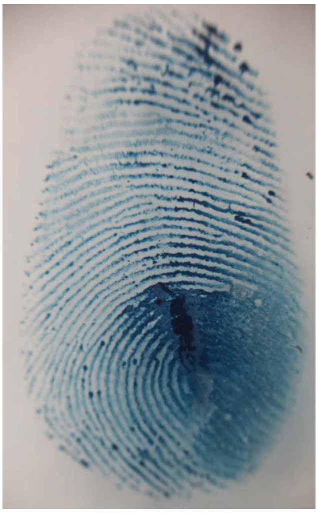


Figure 13.3 A patent print in blood developed with amido black.

The water-based formulation is not as effective as the methanol formulation, as the resulting prints are lighter in color.[9]

Other blood reagents have been developed to visualize latent bloodstains or enhance visible bloodstains on porous items. Ninhydrin, 1,2-indanedione, and DFO all react with proteins on porous substrates. *Acid violet 17* is another fingerprint reagent used to process bloody prints on porous items. Acid violet is a protein dye stain that results in visible prints. The process for developing bloody fingerprints with acid violet is identical to amido black (Appendix B). The fingerprint is "fixed" on the surface, stained, and rinsed. The formulations are almost identical, although it may take more time for the acid violet prints to develop. Acid violet has been shown to be as effective as amido black on porous substrates.[10]

Dark backgrounds pose a problem when attempting to visualize latent or patent fingerprints. Staining a bloody friction ridge impression black (with amido black) or purple (with acid violet) would not be advantageous on a black or dark-colored background. A fluorescent reagent and/or a white powder suspension are needed to visualize bloody prints on dark or patterned substrates.

Acid yellow 7 is a nonporous fingerprint reagent that causes bloody prints to fluoresce, or glow, under blue-green light (385–509 nm) (Appendix B).[11] The resulting prints glow yellow or green in color. Acid yellow has been shown to be more effective on faint impressions in blood than on heavy deposits of blood.[11] Because this chemical is fluorescent, it is used to effectively visualize blood prints on dark or patterned nonporous substrates.

Another effective reagent for processing blood prints on nonporous surfaces is *Small Particle Reagent-White* (*SPR-W*). It is a powder suspension of molybdenum disulfide used mostly on wet vehicle exteriors. It has been shown to be more effective than acid yellow for processing bloody prints on dark, nonporous surfaces.[12]

The suggested sequence for processing bloody prints on porous items is as follows:

- 1,2-Indanedione
- DFO

Table 13.2 **Reagents Effective for Processing Blood Contaminated Prints by Substrate Type**

Substrate	Reagent(s)
Nonporous, dark, or patterned	Acid yellow 7, VMD
Nonporous, light	Amido black, VMD
Porous, dark, or patterned	1,2-Indanedione, DFO
Porous, light	Acid violet 17, amido black

- Ninhydrin
- Amido black or acid violet
- Physical developer

The suggested processes for developing bloody fingerprints on nonporous items are: VMD, SPR-W, Acid yellow, acid violet, or amido black (depending on availability, and the color and pattern of the substrate). Table 13.2 lists all blood processing techniques.

13.4 Metallic Substrates

Metallic substrates such as guns and ammunition have historically posed a challenge for fingerprint analysts. According to the United States Department of Justice, National Institute of Justice statistics, guns were used in 68% of homicides, 41% of robberies, and 21% of violent assaults in 2011 in the United States.[13] As guns and ammunition are frequent evidentiary items found at violent crime scenes and battlefield sites worldwide, it is imperative to achieve success when processing these items for latent prints. There is a low success rate for latent print recovery on metallic surfaces, especially on cartridge casings. Pratt reported a 13% rate of recovery on firearms, 7.6% rate of recovery on gun magazines, and 0.12% recovery rate on cartridge casings.[14] In this study, all items were processed with CA and Rhodamine 6G. Prior to discussion about how to process weapons and ammunition for latent prints, it is important to discuss the standard terminology and understand how weapons function.

There are two main classes of guns: long guns and handguns. Long guns are either shotguns or rifles. Shotguns fire a cartridge full of small projectiles, while rifles fire individual projectiles. Handguns include pistols and revolvers, both of which fire single projectiles, known as cartridges or rounds. What is commonly referred to as a "bullet" is actually a cartridge that contains not only the projectile (the bullet) fired from the gun but also the cartridge casing, the primer, and the gunpowder (Figure 13.4). The cartridge casing houses the gunpowder and primer cap. The primer cap contains a minute amount of explosive material that initiates the burning of the gunpowder. When the gunpowder burns, it creates pressure that forces the projectile out of the cartridge, down the barrel, and out of the gun.

All guns have similar structures for similar function. The barrel of the gun is a steel tube that directs the path of the projectile when it is fired. A barrel has a caliber, or size, based on the diameter of its opening. The size of the projectile that is used in that weapon is also known as its caliber. For example, a 9-mm pistol has a barrel whose opening is 9 mm in diameter. It fires 9 mm (or slightly smaller) cartridges.

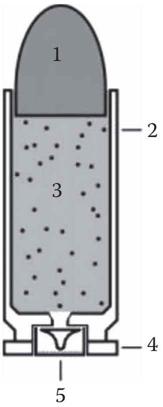


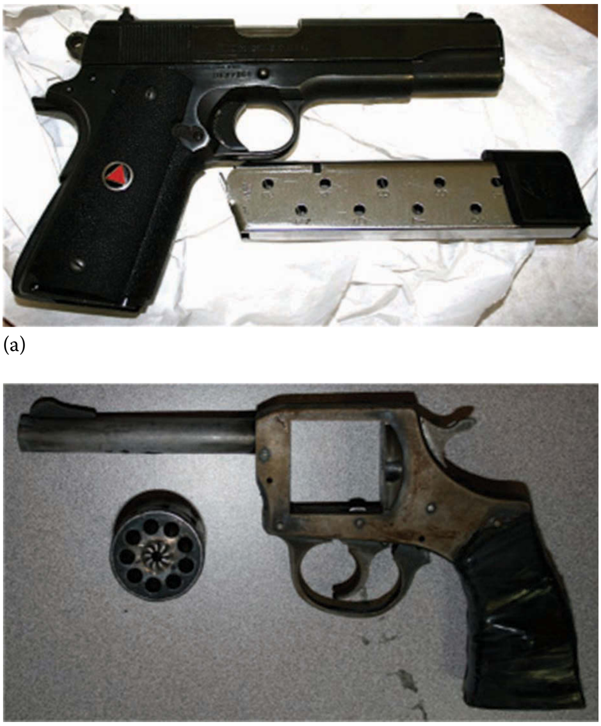
Figure 13.4 A schematic of a cartridge containing a bullet (1), cartridge casing (2), gunpowder (3), rim (4), and primer cap (5). The cartridge case is the most viable surface for developing latent prints on cartridges.

The chamber is the part of the gun in which the cartridge is held before firing. A gun may have a magazine to hold multiple cartridges or, in the case of a revolver, a revolving cylinder into which the cartridges are loaded (Figure 13.5). When a bullet is fired from a pistol or rifle, the gunpowder is burned and consumed, and the empty cartridge casing is ejected from the chamber. Unlike pistols and rifles, when a revolver is fired, the empty cartridge casing remains in the cylinder.

Regardless of the weapon used, it is possible to develop latent prints on all of the exposed metallic surfaces: the exterior of the gun, the magazine, the cartridge, or the cartridge casing. Cartridge casings are especially difficult surfaces for fingerprint analysts. The Israel National Police found that the heat of the explosion that forces the bullet down the barrel also expands the cartridge casing, causing friction between the steel chamber and the casing, which may obliterate any latent prints present.[14] The process of ejecting the casing also results in friction between the surface of the casing and the barrel of the gun. And finally, when the ejected casing falls to the ground, it can roll around and be acted upon by physical and environmental forces. Any or all of these processes can obliterate latent prints.

The weapon itself also poses a problem for fingerprint analysts. Many guns have "fingerprint-resistant" coatings. Most guns have textured surfaces where one handles the weapon when firing it. These textured surfaces help the individual keep a firm grip on the gun; however, they are not suitable for latent print development. Likewise, ribbed gun triggers cannot be processed for latent prints due to their textured surfaces. However, there are smooth surfaces on a firearm that may be processed for latent prints.

Guns are generally made of steel. Cartridge casings may be made of any number of metals and alloys (mixtures of metals) including brass, copper, nickel, steel, or aluminum. Perspiration is acidic and may cause latent prints to be etched on the cartridge surface without using any chemical development techniques. These fingerprints are patent and can be photographed in situ. Following the visual examination phase, the most common methods for developing latent fingerprints on metallic surfaces are CA fuming and CA vacuum processing. The prints developed using these methods are often not readily visible to the human eye and must be dye stained in order to visualize the developed prints.


(a)

(b)

Figure 13.5 A semi-automatic pistol and pistol magazine (top) and a revolver with a cylinder (bottom).

Gun bluing is another process used to develop latent prints on metallic surfaces, especially cartridge casings. Gun bluing is an oxidation process used commercially to rustproof guns. It creates a blue/black finish that is rust resistant. The process involves depositing selenium and copper on the metallic surface.[4] If there are latent prints on the surface, the reaction will occur everywhere except where friction ridge impressions are deposited, similar to the VMD reaction discussed in Chapter 12. The gun bluing reaction produces light-colored fingerprints on a blue/black background. This process is most often used to process cartridge casings for latent prints.

Fingerprint analysts use various gun bluing formulations depending on the metal composition of the cartridge casings. Different formulations work better on different metals and alloys. Regardless of the formulation chosen, it can be used in sequence after the CA vacuum process. Leben and Ramotowski examined the effects of commercially available gun bluing formulations and dilutions on common cartridge cases.[15] These processes tabulated in Table 13.3 were completed after CA development.

Girelli et al. found that the sequence of CA fuming followed by gun bluing and BY40 resulted in the most successful latent print recovery for cartridge casings.[16] A recent study by the Royal Canadian Mounted Police explored an alternate form of gun bluing.[19] They applied an electric current to a fired cartridge case suspended in gun bluing solution.[19] A 1.5 V C battery was used to charge the solution.[19] This electrodeposition of gun bluing reagent was a successful and an efficient technique for processing brass- and nickel-plated cartridge cases.[19]

Table 13.3 Gun Bluing Reagents and Dilutions for Cartridge casings

Cartridge Type	Treatment	Gun Blue (GB) Dilution [GB (ml):Water (ml)]
Nickel-plated brass	Brass Black®	1:40
Brass	Formula 44/40®	0.5:40
Lacquered steel	CA fuming	N/A
Aluminum	Aluminum Black®	0.5:40

Prior to processing any type of weapon for latent prints, it is imperative that the fingerprint examiner renders the weapon safe. Take care to safely remove any live rounds of ammunition that may be in the chamber of the weapon, if this has not been done already. This renders the gun safe to handle. If the gun is not cleared, it may fire and injure or kill the analyst or any surrounding personnel. It is also recommended to consult a firearms examiner prior to processing firearms for latent prints, as some processing techniques such as acidified hydrogen peroxide may interfere with subsequent firearms analyses.[20]

13.5 Skin

Useable, identifiable latent prints on human skin are exceedingly rare. Although there has been some success in developing latent prints on human skin in the research literature, in practice it is not as common. Research is done in a laboratory environment where most variables can be controlled. Both indoor and outdoor crime scenes are generally not controlled environments. There are also many variables that affect latent print deposition on skin such as temperature and humidity fluctuations, exposure, insect activity, human intervention, and weather. Live victims may wipe off prints with their hands, soap and water, or clothing. Deceased victims may be exposed to the elements or insect activity. Each variable presents another challenge that decreases the probability of finding a latent print on human skin.

The skin itself poses challenges to the fingerprint recovery effort. Until death, skin is a regenerating organ that is part of a living, metabolizing organism. Skin cells are constantly reproduced deep in the epidermis and pushed up to the surface where dead skin cells are sloughed off. Skin transfers sweat to the surface. It responds to temperature changes. It has variable surface textures and hair follicles. There is a vascular network just beneath the surface; blood pumped through veins, arteries, and capillaries is constantly in motion. The environment also acts upon the skin. There may be lotions, oils, cosmetics, or other contaminants on the skin. Also, a latent print on skin is composed of the same eccrine and sebaceous deposits as the substrate it is deposited on. These are just some of the processes that contribute to the diverse range of conditions and variables that contribute to a lack of success for fingerprint analysis.

In a review of methods and a survey of forensic scientists working in the field, Sampson and Sampson found that the following variables influence whether or not a fingerprint will be deposited and will persist on human skin: surface temperature of the skin, relative temperature of the environment, humidity, the condition of the skin surface (decomposition), and exposure.[21] The exposure will depend on the location of the scene, whether it is indoors or outdoors, the weather, or the presence or absence of clothing. After death, metabolism stops. The skin dries and cools. In this condition, many of the limiting variables for processing latent prints on human skin are eliminated. Therefore, if a suspect touches a victim after death, there is a greater chance of obtaining useable latent prints.

Working with a deceased victim is challenging. In the United States, there are legal and safety considerations when handling a dead body. A body at a crime scene may not be handled or manipulated in any way by any personnel other than the coroner, medical examiner, or their personnel. The fingerprint analyst may ask for permission to attempt to process the body for latent prints at a crime scene or during an autopsy, but permission may not be granted. If permission is granted, there are safety issues to consider. The body may harbor dangerous pathogens. Suitable personal protective equipment must be worn at all times. It is recommended to use disposable supplies wherever possible to limit the chance of exposure or cross contamination.

The first known murder conviction from an identification of fingerprints from human skin in the United States occurred in Florida in 1978.[21] The case was dubbed "the spa murders" as the three homicide victims were shot to death in a health spa. Three latent prints were developed with Kromekote® cards and black magnetic fingerprint powder. The prints were recovered from the ankle of one of the victims, a nude female who may have been sexually assaulted. One of the fingerprints was identified as the suspect's. The latent print had investigative value because it proved physical contact with the victim.

Since the 1970s, more than 70 methods for recovering latent fingerprints from skin have been reported.[21] The first step in any recovery attempt is to identify what Sampson and Sampson call a "target area." They describe the likely areas for latent print recovery on human bodies:

> A target area is defined for these purposes as an area of exposed surface skin that is suspected of having been touched by the perpetrator. The establishment of target areas is based on certain indicators. Indicators are the position of the body; evidence that the body was moved; partially clad remains; nude body; redressed, posed or displayed body; eye witness account(s); and in the case of a living person, information provided by the victim. Case histories report that victims' bodies were frequently handled by the extremities with prints being recovered from the ankles, wrist, and under the armpits. Other areas where prints have been found are the neck, abdomen, small of the back, buttocks, and inner thighs.[21]

Bruising, reddened skin, bindings, and ligatures can also provide target areas for latent print processing.

Sampson and Sampson also suggest the ideal humidity and temperature for recovering latent prints on skin. The ambient humidity should be between 40% and 60%.[21] This is a normal, comfortable level for most people. The ambient temperature should be between 20°C and 68°C.[21] The body temperature of a deceased subject should be between 20°C and 25.5°C.[21] The skin of a live victim should be between 29°C and 30°C.[21] The skin of a live victim can be cooled with a fan prior to using any of the following development techniques.

There are three categories of techniques for developing fingerprints on human skin: the direct transfer method, fingerprint powdering, and chemical reagents. These chemical reagents include amido black and CA fuming. All these processes are limited to relatively fresh prints and are infrequently successful. The most success is accomplished when the impressions are patent blood prints.

The direct transfer method is the most effective technique for processing latent prints on skin both in the laboratory and in the field. After a target area has been identified, a

Figure 13.6 A latent print developed on human skin using the direct transfer method. The glossy side of a fingerprint card pressed to a target area of skin on a live victim developed with black magnetic fingerprint powder.

transfer medium is pressed to the skin to transfer the latent print. The most widely used and successful transfer medium is a Kromekote card. Kromekote cards are white, ultra glossy cards similar in texture to photo paper. They are widely available from printing companies. In 1978, Reichardt et al. found this technique to be successful even when skin has been submerged in water.[22]

In the direct transfer process, the transfer medium is pressed, glossy side down, onto the target area with firm and even pressure. The card is carefully lifted from the surface, taking care not to smear latent prints in the process. The transferred latent print is then developed on the card with black magnetic powder (although regular black powder can be used) (Figure 13.6). The resulting print is a reversal, or mirror image, of the original print. It can easily be photographed or scanned into an image-processing program and digitally reversed.

The powder method is somewhat less successful than the direct transfer method. The skin is dusted with black magnetic fingerprint powder (Figure 13.7). The resulting print may be lifted with tape or a silicone rubber lifting material.

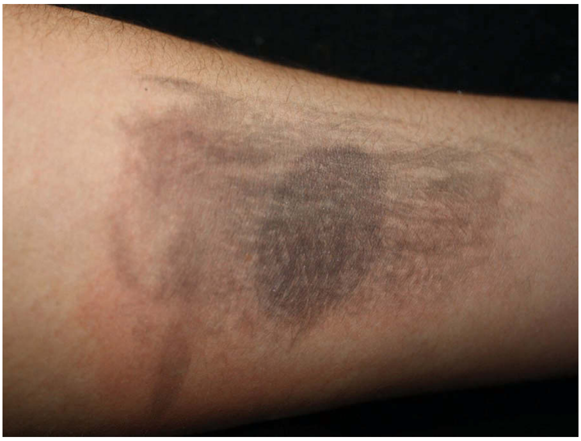


Figure 13.7 Black magnetic fingerprint powder dusted onto a target area of skin reveals a latent print.

Regardless of the method used, it may also be possible to extract DNA from latent prints on skin. It is more likely that the DNA of the victim will be amplified rather than the DNA of the suspect, because the fingerprint residue (containing touch DNA) is placed on the skin of another individual. Färber et al. found that 2% of DNA profiles from prints lifted from human skin were identified to the donor.[23] The Färber study was, however, completed in a controlled laboratory environment. The DNA recovery percentage might be lower if the prints were collected at a crime scene or during an autopsy. Just because the success rate is low does not mean it should not be attempted. If prints recovered from human skin are not of good enough quality for fingerprint comparison purposes, they may be swabbed for touch DNA.

13.6 Adhesive Substrates

Adhesive substrates include tapes, stamps, and labels. Any item with a sticky surface may contain not only friction ridge impressions but also skin cells stuck to the surface. When an individual pulls a piece of tape from a roll, it is necessary to touch the sticky side of the tape. When the tape is ripped from the roll and applied to another surface, the ends of the tape must be handled. It is therefore the edges and ends of adhesive substrates that are most successful for developing latent prints. The most successful methods for processing the adhesive sides of tape include the use of liquid powder suspensions or a chemical reagent called crystal violet.

The first issue to address when processing the sticky side of the tape is how to expose the sticky side. Tape, labels, and stamps are often stuck to other objects and must be removed without damaging latent prints on the adhesive side. There are several methods for loosening tape from another substrate, or from itself. If possible, gently peel the adhesive loose with gloved fingers and forceps. If the tape is stuck to itself or to another nonporous item, it can be frozen to reduce the tackiness of the adhesive. Adhesive can also be loosened with a hair dryer or heat gun, but this may cause the substrate to melt and stretch, resulting in poor quality or distorted latent prints.

If the adhesive is stuck to a porous substrate, such as a stamp or address label on an envelope, a chemical adhesive remover such as Un-du® may be used. Adhesive remover is found in the scrapbooking section of craft stores or purchased from any major forensic supplier. These solvents should be used very sparingly so as not to affect the integrity of the substrate or obliterate the latent print. Adhesive removers such as Un-du® do not have a negative effect on latent print processing.[24]

As with any other substrate, it is important to consider the color of the adhesive before picking a development method. Clear or light-colored tapes were historically processed with crystal violet, also known as Gentian violet. *Crystal violet* is a fat-soluble stain for clear tapes such as Scotch® tape or packing tape (Appendix B).[25] This process results in purple friction ridges on a light purple background (Figure 13.8). Unfortunately, crystal violet is a suspected carcinogen and has been removed from many processing sequences.

Light-colored adhesives are processed with a black powder suspension. Commercially available powder suspensions such as sticky-side powders and Wetwop™ may be purchased from any forensic supplier. Fingerprint powders are mixed with a 50:50 blend of water and detergent (such as Liquinox® or Triton X-100-ethylene glycol solution) to reach the consistency of paint (Appendix B). Powder suspensions are painted onto the adhesive

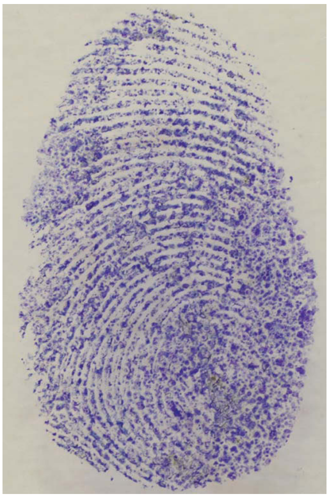


Figure 13.8 A latent print developed with crystal violet.

surface with a camelhair brush (Figure 13.9). The solution is left on the surface for 10–60 s and rinsed with tap water. The procedure can be repeated until good contrast is achieved (Figure 13.10).

All of these solutions utilize a detergent component, which allows the colored powder to bind to the oils in the fingerprint residue. Powder suspensions are also available in white, gray, and fluorescent for processing dark-colored tapes such as black electrical (vinyl) tape. Most adhesive substrates also have a nonporous or semiporous non-adhesive side. The non-adhesive side of the tape also has forensic value. Traditional nonporous processing methods are used prior to processing the adhesive side of the tape. The following is a recommended sequential process for adhesive substrates:

- CA fuming
- Adhesive-side powder suspension
- CA dye stain

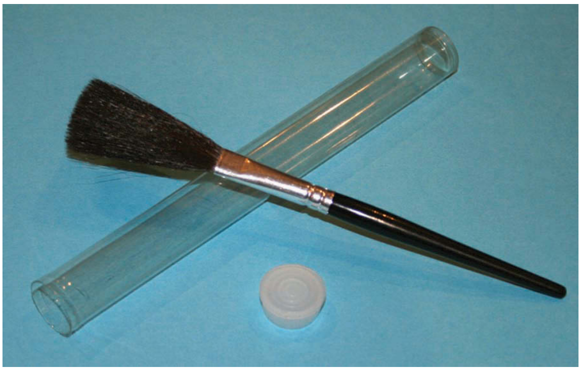


Figure 13.9 A camel hair fingerprint brush.

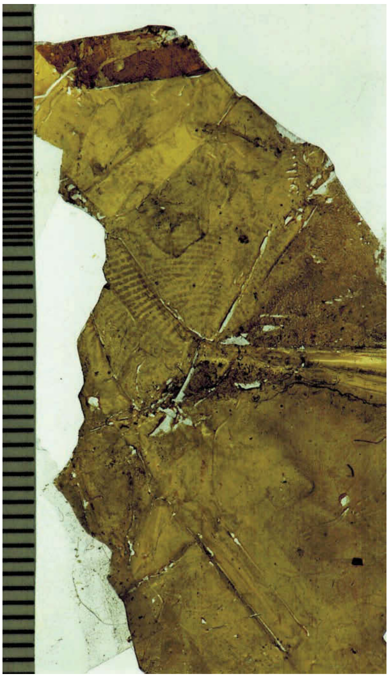


Figure 13.10 A latent print on packing tape developed with black fingerprint powder suspension.

Although crystal violet has been removed from sequential processes, adhesive side powder suspensions are effective. Adhesive substrates are some of the most expedient surfaces for developing latent prints.

13.7 Thermal Paper

Thermal papers are a special case of porous substrate. They include chemically treated papers such as receipts. The polar reagents utilized on most porous substrates would result in the thermal paper darkening or turning black when the substrate is heated. Therefore, traditional methods of processing with DFO and ninhydrin would not be effective.

A specially formulated version of ninhydrin, called ThermaNin, has been developed for use on thermal papers. Indanedione is a nonpolar reagent and can be used to process thermal paper for latent prints. Research has shown that both ThermaNin and indanedione are equally effective.[28] Fitzi et al. suggested the following processing sequence for thermal paper based on nonpolar formulations of all reagents listed below:[29]

- Visual examination
- Indanedione
- Ninhydrin
- Oil red O
- Single metal deposition

If ninhydrin is the only chemical reagent available, it can be used via an alternate development process. First, two sheets of plain, non-evidentiary paper are saturated with ninhydrin and dried in a fume hood. Then, the thermal paper is sandwiched between the two dry ninhydrin-treated sheets and sealed in a zip-top plastic bag. The bag is put in a dark place overnight, allowing ninhydrin fumes to develop the latent prints rather than the aqueous solution.

A similar reagent, p-dimethylaminocinnamaldehyde (known as pDMAC), is available through forensic vendors. This system includes pDMAC coated paper and a sealable metallic sleeve. The thermal paper is placed between the pDMAC papers, sealed in the metallic sleeve, and compressed with a heavy object such as a book for 20–30 min.[30] The resulting prints are fluorescent, so this process is useful for dark or patterned thermal substrates. The fluorescence can be visualized with green light (at 475–515 nm) and an orange barrier filter or orange glasses.[30] As thermal papers are common evidentiary items—in the form of receipts or number tickets—it is important to have a plan for processing these items of evidence.

13.8 I Had a Case: The Janitor in the Drum

A 55-gallon steel drum that had been dumped in a park drew the attention of passersby when it began to emit a strong odor. Police were called and soon suspected that something was decomposing inside. The drum was sealed with concrete and wrapped with duct tape. The drum was removed to the coroner's office for examination, where two bodies were found sealed in the drum: a female victim and a male victim later identified as a local janitor.

The first task in opening the drum was to remove the duct tape. A fingerprint examiner prepared a large batch of crystal violet in an improvised dishpan. Layer by layer, the tape was slowly unwound, passed through the solution, rinsed, and inspected for latent prints. Results were discouraging until the last section of 100 feet of tape. A high-quality right thumbprint was found. The fingerprint was later identified to the murder suspect. It is not uncommon in processing strips of tape that the last piece removed for testing had been the first piece applied by the criminal. Why do you think this is so?

13.9 Chapter Summary

There are various methods for processing greasy latent prints, bloody prints, prints on metallic surfaces, prints on skin, and prints on adhesive surfaces. The technique employed depends on the type, color, and condition of the substrate in question. For greasy substrates or oily fingerprints, natural yellow 3 and white powder suspensions are used on nonporous dark or patterned substrates; Sudan black is used on both nonporous and porous, light-colored substrates; and oil red O is used on porous, light-colored substrates. For bloody fingerprints, acid yellow is used on nonporous dark or patterned substrates; amido black is used on both nonporous and porous light-colored substrates; and acid violet is used on porous, light-colored substrates.

Metallic surfaces, such as firearms and their components, are processed via CA fuming followed by dye staining. Cartridge cases are processed with a gun bluing reagent, taking into consideration the composition of the metal. Skin can be processed for latent prints using the direct transfer method. This method utilizes a Kromekote card pressed against the target area to transfer a latent print that is then visualized with black powder. Adhesive substrates can be processed with powder suspensions that contrast with the substrate. Thermal paper is processed with nonpolar formulations of porous fingerprint processing reagents.

13.10 Review Questions

1. List five common surfaces or areas where greasy or oily prints may be found.
2. What chemical reagent(s) would be used to develop an oily print on a navy blue colored envelope?
3. What chemical reagent(s) would be used to develop an oily print on a white sheet of paper?
4. Acid yellow 7 is used to develop bloody fingerprints on what type of surface, and why?
5. Which chemical reagent(s) would be used to develop a bloody print on any type of light-colored surface?
6. Acid violet is a chemical reagent that enhances what type of latent print matrix? Give an example of a type of surface on which one would use this reagent.
7. What is the oxidation process called by which a gun is coated with selenium and copper to make it rust resistant?
8. Describe the direct transfer method of developing a latent print on human skin.
9. How is a strip of black electrical tape processed for latent prints?
10. Why is it important to use nonpolar versions of fingerprint reagents to process thermal paper?

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Fingerprint Analysis

III

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Documentation

14

> We strive to avoid a justification for individualization that only revolves around the tautological argument that every entity in nature is unique. The permanence and selectivity of friction ridge skin should be fully understood from a biological perspective and then applied in assessing fingermark comparisons.
>
> **C. Champod**[1]

LEARNING OBJECTIVES

- Describe the various types of documentation completed by the fingerprint analyst.
- Define "chain of custody" and explain its purpose and importance.
- Name the types of lenses and filters used to visualize and photograph latent print evidence.
- Explain the four most common photographic techniques for recording latent prints on evidentiary items, and describe which latent print development techniques are best captured with each method.
- Explain the process of digitally storing and enhancing latent print images.
- Explain the purpose and content of a final report.

14.1 Documentation

Documentation is the process of recording the details of your forensic process, analysis, and results. Documentation may take several forms including photography, note taking, filling out worksheets and forms, and/or completing a formal narrative report. Every scientific discipline requires thorough documentation to record hypotheses, processes, results, and conclusions. This is integral to the scientific method. The forensic sciences rely on these processes not only to record the scientific methodology but also to complete a thorough record of unbiased facts and observations for future use in a court of law (Chapter 18).

Documentation allows forensic examiners to "compare notes," especially if they reach different conclusions. For example, it is possible for one latent fingerprint examiner to deem a latent print "inconclusive" while another determines it is an "exclusion" or "identification." This difference in opinion requires a conflict resolution process that is best achieved by examining the fingerprint examiner's process through their documentation. The Expert Working Group on Human Factors in Latent Print Analysis stated:

> A report and contemporaneous supporting notes or materials should document the examination to make the interpretive process as transparent as possible. Although the degree of

> detail may vary depending on the perceived complexity of the comparison, documentation should, at a minimum, be sufficient to permit another examiner to assess the accuracy and validity of the initial examiner's assessment of the evidence.[2]

Documentation of forensic processes includes extensive note taking at the crime scene, in the laboratory, and during the analysis phase; photography before, during, and after each process; the completion of forms and agency-prepared documents; and the preparation of visual aids such as charts or photographs for use in court proceedings. A fingerprint analyst may complete the following documentation: photography, sketches, a chain of custody, forms required by the agency or department, worksheets, notes, reports, and visual aids for court testimony.

An agency or department may require that the fingerprint analysis follow a specific set of guidelines known as *standard operating procedures (SOPs)* for documenting evidence and fingerprints. Regardless of the methods or documentation format used, the fingerprint analyst must be as thorough as possible, recording every detail with integrity and without bias. Documentation must include every detail of processing, analysis, and interpretation from the time evidence is received until it is signed over to someone else or until the case is closed. This chapter addresses common methods of documentation including laboratory notes, worksheets, and forms; photography; and final reports.

14.2 Contemporaneous Notes and Forms

Bench notes are informal notes describing the analyst's process, analysis, results, and conclusions. Notes should be *contemporaneous*, meaning that they should be taken as the actions are performed, or soon after. This ensures accuracy and transparency. Some departments or agencies require forensic scientists to utilize designated forms, software, or worksheets for note taking.

Forensic scientists generally write any of three types of notes: crime scene processing notes, laboratory processing notes, and/or notes detailing analyses and conclusions. A fingerprint examiner writes detailed notes about latent print processing, analyses, comparisons, and conclusions. Notes may include the following:

- Case information
- Your name and identifier (badge number or employee number)
- A detailed description of the evidence (item number and description)
- Steps taken to process the evidence for latent prints
- The results of each process (number of latents developed and identifiers for each latent)
- Photographic methods used to record latent prints
- The disposition of the evidence following processing
- The analysis, comparison, evaluation, and verification phases of the latent print comparison process (Chapter 16)
- Conclusions and resulting expert opinions

The following is an example of laboratory processing notes written in outline form:

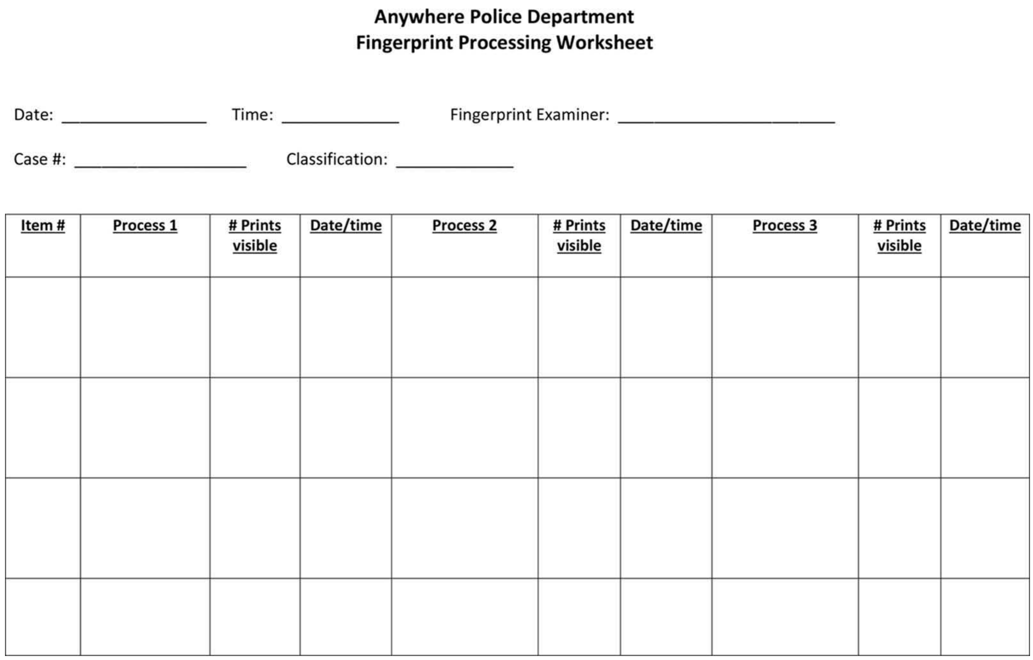
- *Case #2018-01487 was received from Anywhere Police Department's evidence storage facility on July 11, 2018 at 0830 h.*

- *Item #17—Black and silver Samsung mobile phone, "Galaxy S8 Active" s/n 358524081368448.*
- *Visual examination with oblique lighting—no latent prints of value observed.*
- *Superglue fuming—25 min at 60% humidity in superglue fuming chamber yielded one latent print of value on the lower right corner of the mobile phone screen, labeled L001.*
- *L001 was photographed with a digital single-lens reflex (SLR) Nikon D5 camera using oblique lighting.*
- *Fluorescent orange powder—viewed with a Coherent TracER™ laser, yielded no new latents of value other than L001.*
- *L001 was re-photographed with a Nikon D5 digital SLR camera and orange filter.*
- *Photographs were downloaded and saved in the Anywhere Police Department's Laboratory Information Management System (LIMS) as follows*:
  - *201801487_L001A*
  - *201801487_L001B*
- *Item #17 was repackaged and sealed on July 11, 2018, at 1450 h.*
- *Item #17 was submitted to the secured evidence storage facility on July 11, 2018, at 1700 h.*

Note that each step in the process is recorded in detail, along with a detailed description of the evidentiary item itself. Any authorized personnel involved with the case should be able to understand which processes were completed, how they were completed, the results of those processes, and how the resulting photographs can be accessed.

Recent research has focused on the need for increased transparency and documentation in the fingerprint sciences, specifically throughout the latent print comparison process. This will be discussed in detail in Chapter 16. The following is an example of latent print comparison notes written in outline form:

- *Case #2018-01487 was received on July 13, 2018, at 0800 h from the evidence storage facility for the purpose of latent print comparisons. The following latent print evidence was received.*
  - *L001 (photograph L001B from Item #17, black and silver Samsung mobile phone, "Galaxy S8 Active" s/n 358524081368448, front lower right corner of screen)*
  - *L002, L003 (Latent lift #1, from black Lexus RX 350 VIN #2TBK1BA3DB196788, exterior drivers side door handle)*
- *Latent L001 is sufficient for comparison purposes.*
- *Latents L002 and L003 are of poor quality and are not sufficient for comparison purposes.*
- *L001 was compared with the victim (Jane Doe, dob 08-06-1994) exemplar prints with negative results.*
- *L001 was compared to the listed suspect (John Smith, dob 10-01-1993) exemplar prints with the following results*:
  - *Identification: There is a sufficient correspondence of level 1 and level 2 detail between latent L001 and the #1 finger of the listed suspect to conclude that both prints likely come from the same source.*
- *This conclusion was verified by Francis Galton on July 15, 2018.*



Anywhere Police Department
Fingerprint Processing Worksheet

Date: ______________ Time: ____________ Fingerprint Examiner: ______________________

Case #: __________________ Classification: ____________

Item #	Process 1	# Prints visible	Date/time	Process 2	# Prints visible	Date/time	Process 3	# Prints visible	Date/time

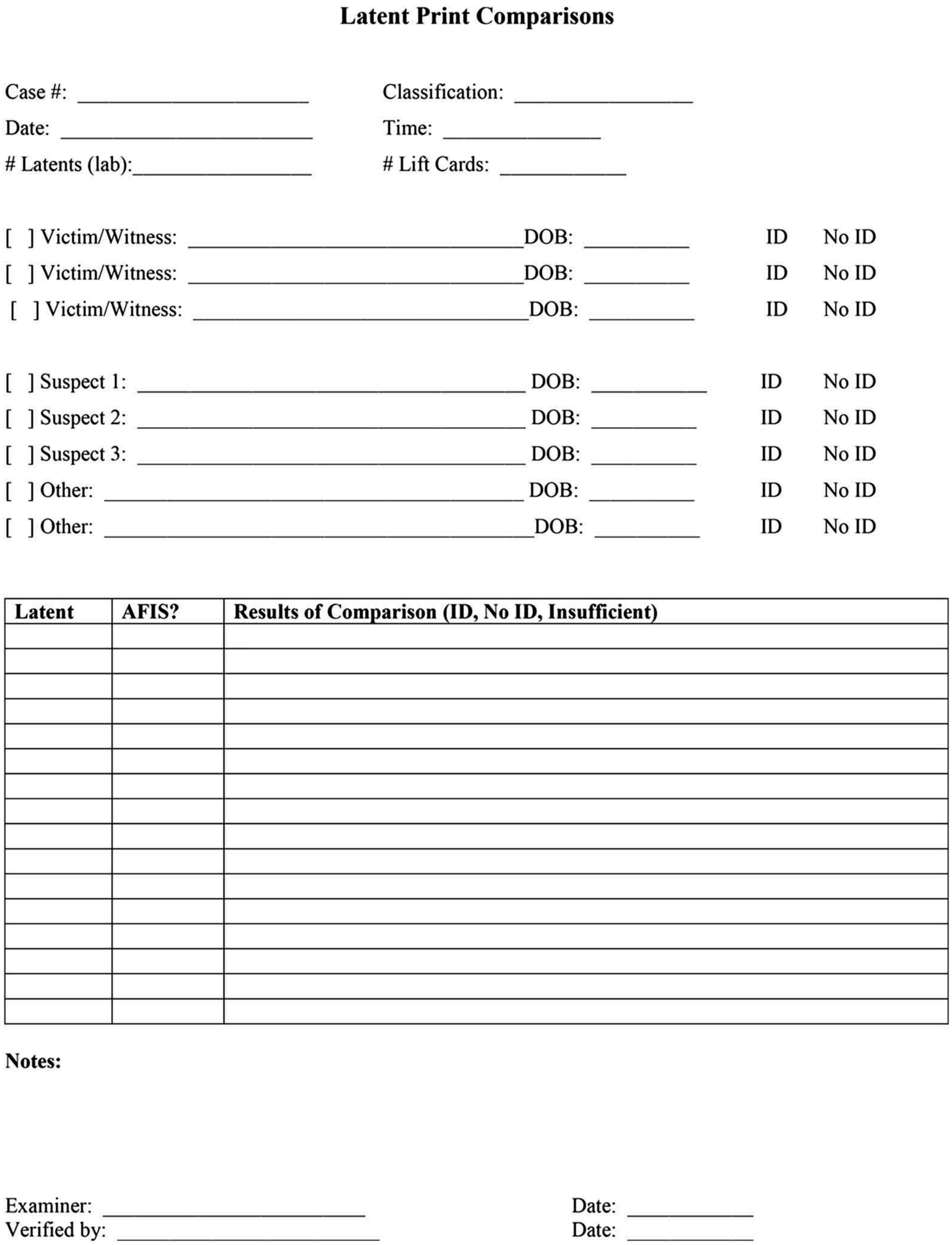
Figure 14.1 Generic blank latent print processing form.

One or more supplemental forms, worksheets, or other documentation may be required, depending on your laboratory's SOPs. Figures 14.1 and 14.2 are examples of generic fingerprint processing and fingerprint comparison forms. Figure 14.3 is an example of a fingerprint comparison form used by the City of Pomona Police Department in Pomona, California. Figure 14.4 is an example of a form fingerprint analysts at the Pomona Police Department use to visually demonstrate the fingerprint comparison process.

The chain of custody is another form used in every sub-discipline of the forensic sciences. The *chain of custody* is a form that records the dates, times, and explanations for evidence transfers. It is, in essence, the autobiography of the life of an evidentiary item from the moment it is identified until the closure of the case it is associated with. The chain of custody accounts for an item of evidence from the date and time it is collected until it is destroyed or stored at the conclusion of a case.

When an item of evidence is collected, a chain of custody form is attached to the evidence package. The individual collecting or taking custody of the item fills out the form and signs his or her name, recording the date and time the item was collected, and the description of the item. As long as the item is in that individual's possession, the chain of custody remains unchanged. When the item changes hands—for example, if it is submitted to a DNA analyst for DNA testing—an individual at the DNA laboratory will sign his or her name on the form and record the date and time of the transfer, thereby officially taking custody of the item (Figure 14.5).

The individual with custody of the evidence is responsible for the condition and integrity of that evidence until it is signed over to someone else. Every transfer, no matter how brief, is documented on the chain of custody form. If the evidence must be left unattended,



Latent Print Comparisons

Case #: ____________________ Classification: ________________
Date: ______________________ Time: ______________
Latents (lab):________________ # Lift Cards: ___________

[ ] Victim/Witness: ______________________________DOB: _________ ID No ID
[ ] Victim/Witness: ______________________________DOB: _________ ID No ID
[ ] Victim/Witness: ______________________________DOB: _________ ID No ID

[ ] Suspect 1: ___________________________________ DOB: __________ ID No ID
[ ] Suspect 2: ___________________________________ DOB: _________ ID No ID
[ ] Suspect 3: ___________________________________ DOB: _________ ID No ID
[ ] Other: _____________________________________ DOB: _________ ID No ID
[ ] Other: ______________________________________DOB: _________ ID No ID

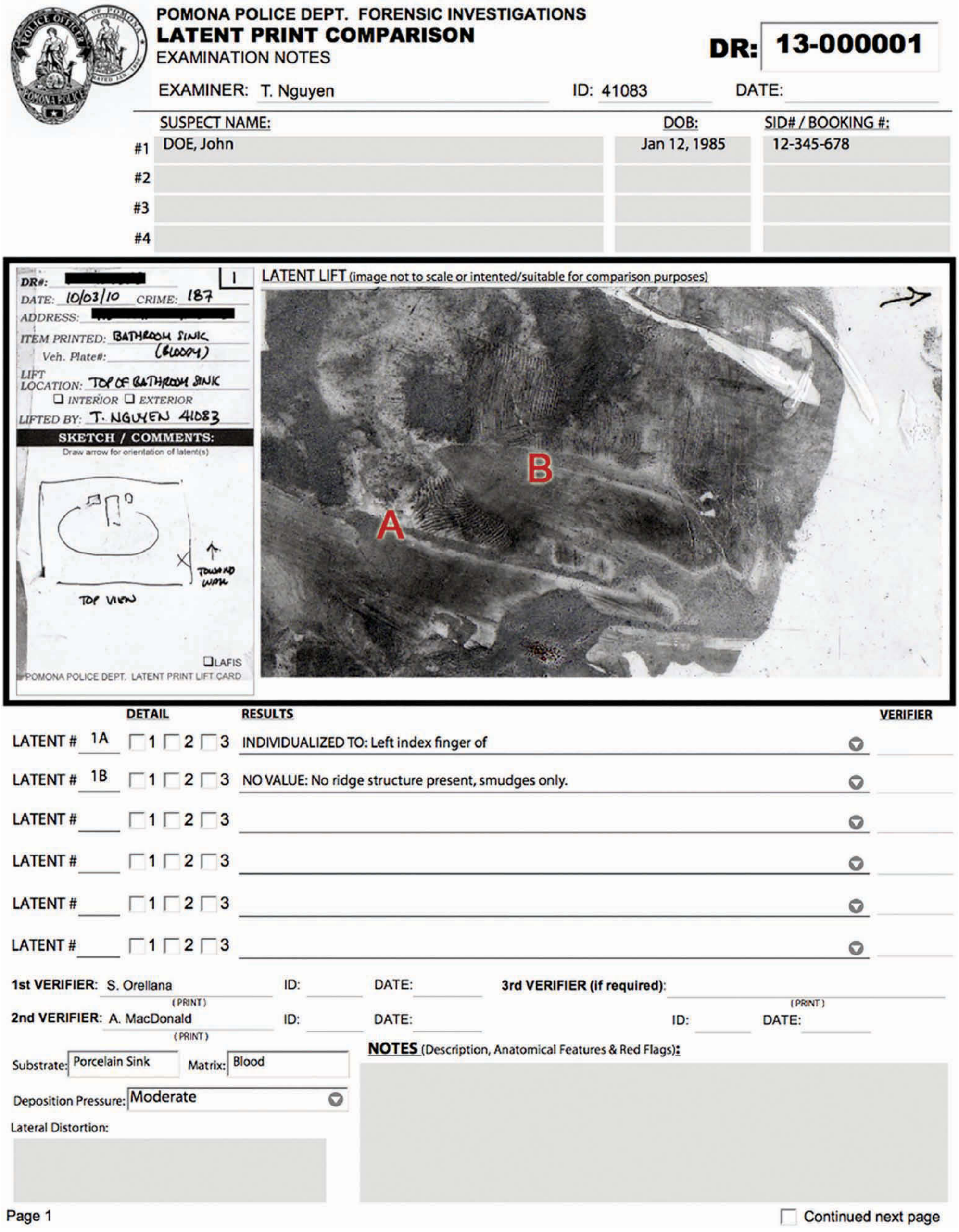
Latent	**AFIS?**	**Results of Comparison (ID, No ID, Insufficient)**

Notes:

Examiner: _______________________ Date: ___________
Verified by: _______________________ Date: ___________

Figure 14.2 Generic blank latent print comparison form.

it is stored in a secure evidence storage facility or evidence locker. The evidence must be accounted for at all times, and it is the responsibility of each individual handling the evidence to ensure that the chain of custody is maintained and accurate. If the chain is broken, and evidence is unaccounted for during any period of time, the integrity of that evidence is compromised. The following questions may arise: “How do we know the



POMONA POLICE DEPT. FORENSIC INVESTIGATIONS
LATENT PRINT COMPARISON
EXAMINATION NOTES

DR: 13-000001

EXAMINER: T. Nguyen ID: 41083 DATE:

	SUSPECT NAME:	DOB:	SID# / BOOKING #:
#1	DOE, John	Jan 12, 1985	12-345-678
#2			
#3			
#4			

DR#: [redacted] 1
DATE: 10/03/10 CRIME: 187
ADDRESS: [redacted]
ITEM PRINTED: BATHROOM SINK (BLOODY)
Veh. Plate#:
LIFT LOCATION: TOP OF BATHROOM SINK
☐ INTERIOR ☐ EXTERIOR
LIFTED BY: T. NGUYEN 41083

SKETCH / COMMENTS:
Draw arrow for orientation of latent(s)

TOWARD WALL
TOP VIEW

☐LAFIS
POMONA POLICE DEPT. LATENT PRINT LIFT CARD

LATENT LIFT (image not to scale or intented/suitable for comparison purposes)

	DETAIL	RESULTS	VERIFIER
LATENT # 1A	☐ 1 ☐ 2 ☐ 3	INDIVIDUALIZED TO: Left index finger of	
LATENT # 1B	☐ 1 ☐ 2 ☐ 3	NO VALUE: No ridge structure present, smudges only.	
LATENT #	☐ 1 ☐ 2 ☐ 3		
LATENT #	☐ 1 ☐ 2 ☐ 3		
LATENT #	☐ 1 ☐ 2 ☐ 3		
LATENT #	☐ 1 ☐ 2 ☐ 3		

1st VERIFIER: S. Orellana (PRINT) ID: DATE: **3rd VERIFIER (if required):** (PRINT)
2nd VERIFIER: A. MacDonald (PRINT) ID: DATE: ID: DATE:

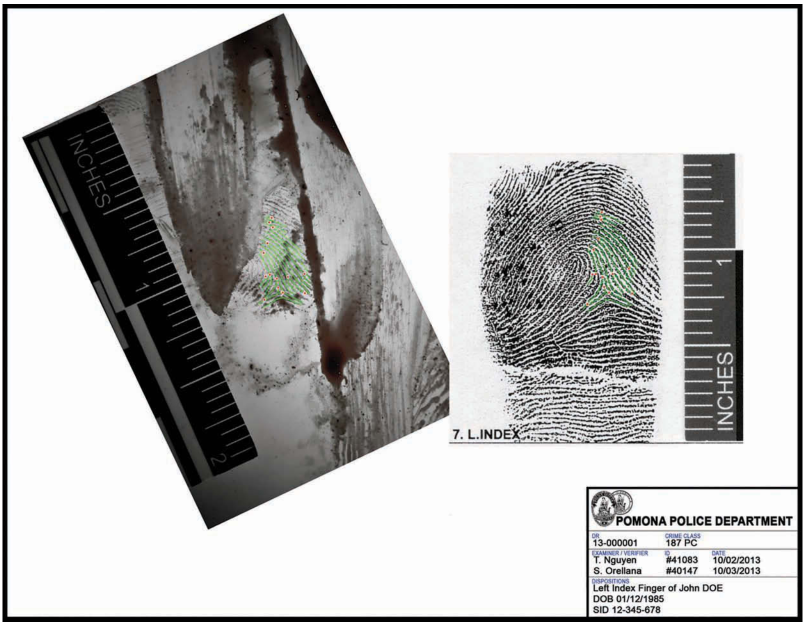
Substrate: Porcelain Sink Matrix: Blood
Deposition Pressure: Moderate
Lateral Distortion:

NOTES (Description, Anatomical Features & Red Flags):

Page 1 ☐ Continued next page

Figure 14.3 A latent print comparison form developed and used by the City of Pomona, California Police Department. (Courtesy of Tony Nguyen, Crime Scene Examiner with the City of Pomona Police Department.)

evidence was not tampered with, forged, or altered during the time it was unaccounted for?" "Was the evidence lost during that time period?" "Do the notes, forms, photos, and final report match up with the timeline documented on the chain of custody, or are there inconsistencies?" The chain of custody is a critical document that must remain with the evidence at all times.



POMONA POLICE DEPARTMENT

DR 13-000001	CRIME CLASS 187 PC	
EXAMINER / VERIFIER	ID	DATE
T. Nguyen	#41083	10/02/2013
S. Orellana	#40147	10/03/2013

DISPOSITIONS
Left Index Finger of John DOE
DOB 01/12/1985
SID 12-345-678

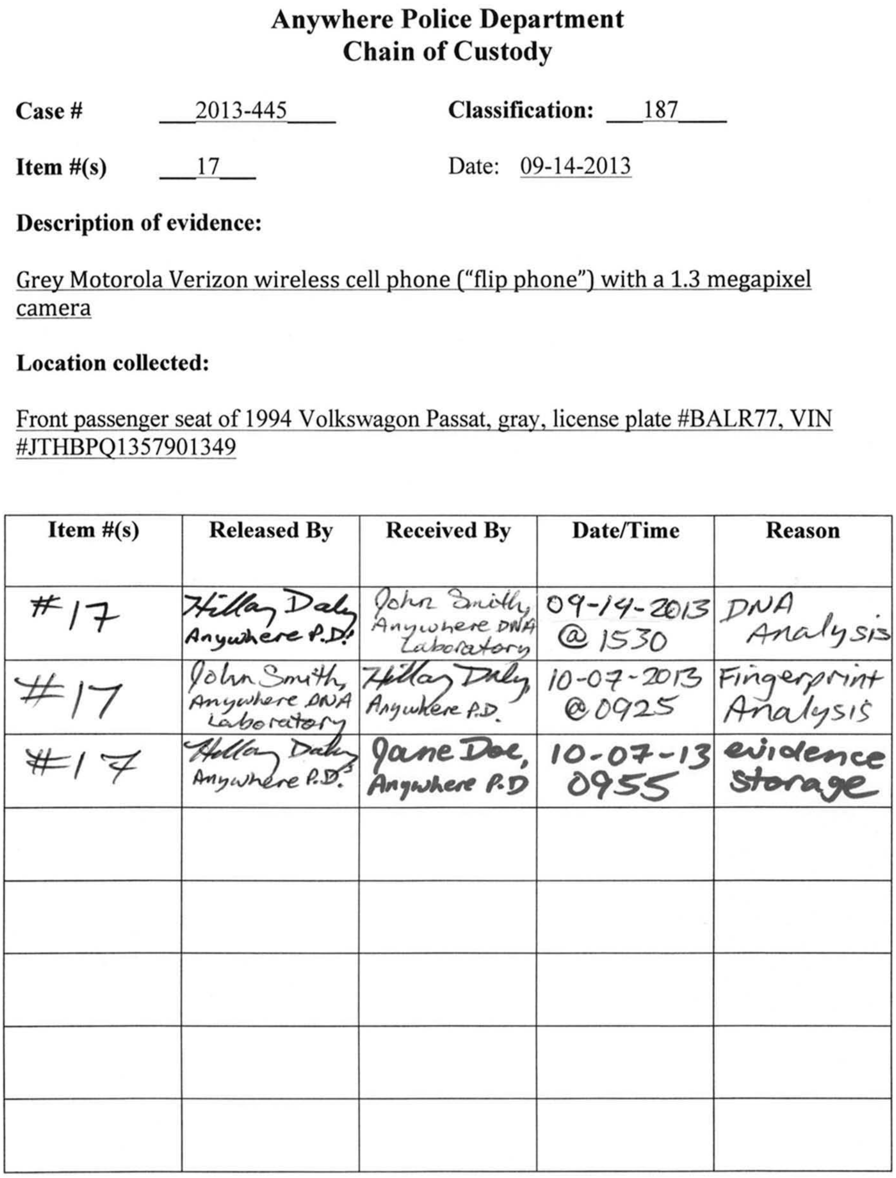
Figure 14.4 A latent print comparison form developed and utilized by the City of Pomona, California Police Department demonstrating the latent print comparison process. (Courtesy of Tony Nguyen, Crime Scene Examiner with the City of Pomona Police Department.)

14.3 Photography

The word photography comes from the Greek root words *phos* (light) and *graphos* (write).[3] Photography is, in the simplest terms, writing with light. Aristotle was the first individual in recorded history to explore how light can be manipulated to project images onto a surface.[3] Photography has been used for documentation in the criminal justice community since the rogues' galleries and portraits parlé of the 1800s (Figure 14.6).[3] These photographs were used to document the physical appearance of criminals for future identification.

The first fingerprint cameras were large format cameras (Figure 14.7). "Large format" refers to the size of the film used in the camera. Large format film is any recording medium 4 × 5 in. (10.2 × 12.7 cm^2) or larger.[4] An example of large format film is Polaroid© instant film. Film photography, most commonly 35 mm film, replaced most large format film cameras. The most popular cameras in use today are digital *SLR* cameras of varying resolutions and models. It is now rare to see either a large format camera or a 35-mm film camera in use at law enforcement agencies and forensics laboratories.

Most individuals either own a mobile phone with a built-in digital camera or have experience using a digital camera. There are many advantages of digital cameras versus film cameras for forensic documentation. Photos taken with a digital camera can be viewed immediately, unlike film cameras, which require the film to be processed and printed before photos can be viewed. They can also be easily stored in a digital format that does not take up space in filing cabinets as printed film photographs do. Digital photos are easily inserted into computer presentation software and used for courtroom testimony. Digital photos can be enhanced on a computer, which is especially useful for enhancing



Anywhere Police Department
Chain of Custody

Case # 2013-445 **Classification:** 187

Item #(s) 17 Date: 09-14-2013

Description of evidence:

Grey Motorola Verizon wireless cell phone ("flip phone") with a 1.3 megapixel camera

Location collected:

Front passenger seat of 1994 Volkswagon Passat, gray, license plate #BALR77, VIN #JTHBPQ1357901349

Item #(s)	Released By	Received By	Date/Time	Reason
#17	Hillary Daly Anywhere P.D.	John Smith Anywhere DNA Laboratory	09-14-2013 @ 1530	DNA Analysis
#17	John Smith Anywhere DNA Laboratory	Hillary Daly Anywhere P.D.	10-07-2013 @ 0925	Fingerprint Analysis
#17	Hillary Daly Anywhere P.D.	Jane Doe, Anywhere P.D	10-07-13 0955	evidence storage

Figure 14.5 An example of a chain of custody form demonstrating the transfer of evidence from the police department to the DNA laboratory and back again to the police department for secured storage.

latent prints for comparison purposes. Another advantage of digital photography is that digital images can be shared efficiently with investigators, attorneys, and other individuals involved with the case. These images are shared via secure email or file sharing. Once the initial camera purchase is made, it is much more efficient and cost effective to use, store, and copy digital photos rather than traditional large format or 35-mm film photos.

Digital cameras have interchangeable lenses, several of which are used in forensic photography. The 50–55 mm *standard lens* and 28–70 mm *multipurpose lens* are often sold with the camera (Figure 14.8).[3] Although these lenses are useful for photographing evidentiary

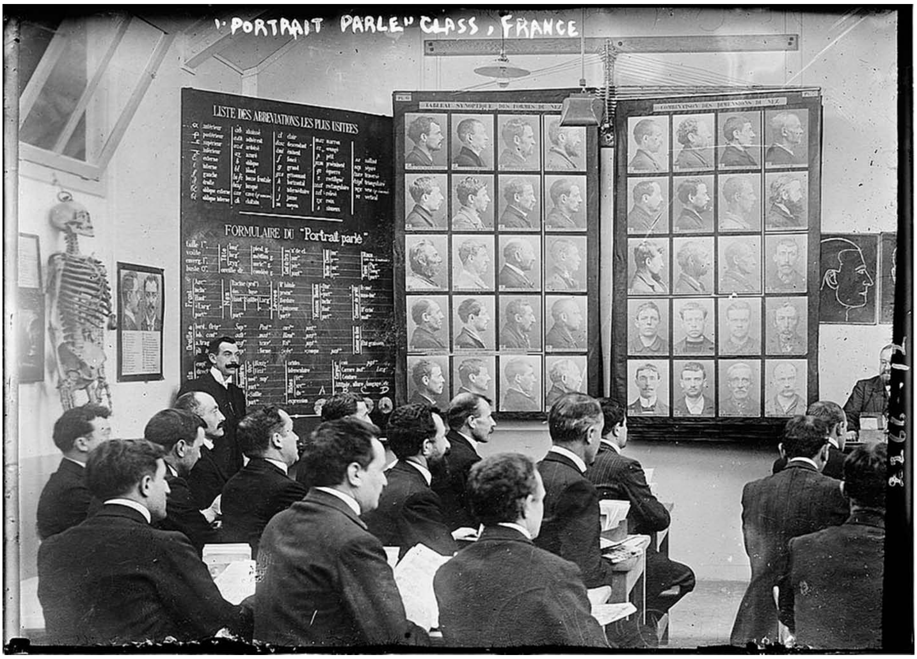

"PORTRAIT PARLE" CLASS, FRANCE
LISTE DES ABREVIATIONS LES PLUS USITEES
FORMULAIRE DU "Portrait parlé"

Figure 14.6 A photograph of a French portrait parlé class, ca. 1910–1915. (Reprinted from the Library of Congress Prints and Photographs Division.)

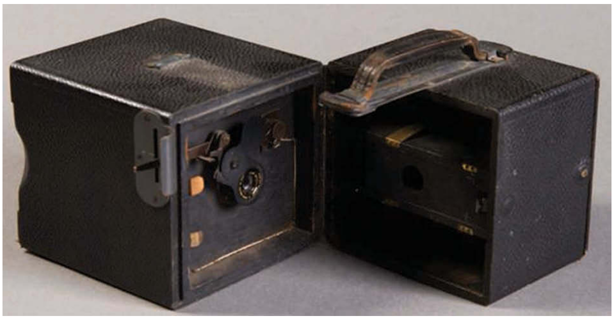


Figure 14.7 The first fingerprint camera. (Reprinted with permission from the People's Collection Wales and the South Wales Police Museum.)

items or crime scenes, they are not sufficient for close-up latent print photography. *Macro lenses* are used to photograph items close-up. They are appropriate for photographing small-scale forensic items such as hairs and fibers, serial numbers, toolmarks, and latent prints.[3]

Flashes are also important components of the digital SLR camera. In Chapter 9, various types of lights were introduced as critical tools for visualizing latent prints. Fingerprint analysts must convey what they see as accurately as possible through the camera lens. Therefore, it is important to use different lighting techniques and camera settings to capture the best image possible. A *detachable flash* can be held at any angle to provide oblique or direct lighting (Figure 14.9). A *ring flash* mounted on the camera lens provides a uniform

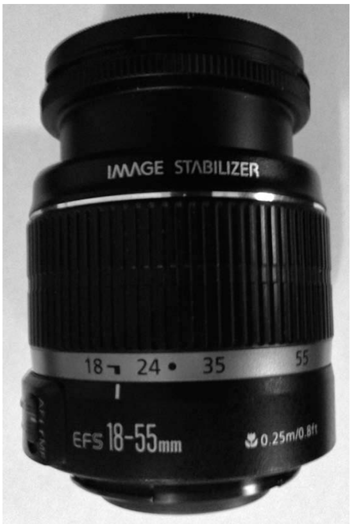


Figure 14.8 A 55 mm camera lens.

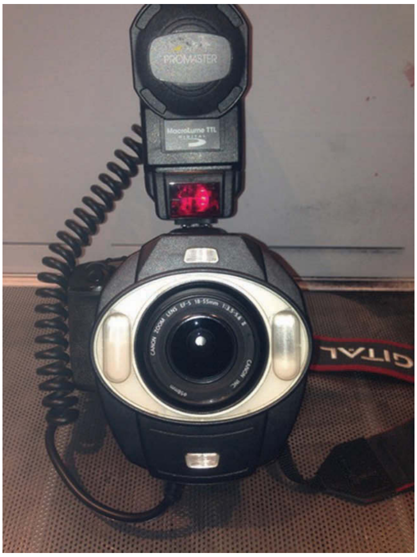


Figure 14.9 A digital SLR camera with a detachable flash and ring flash.

distribution of light around the latent print (Figure 14.9). The camera should be mounted on a tripod or camera stand to keep it steady while the analyst manipulates the light source and composes the photograph.

There are several filters commonly used in forensic sub-disciplines. A filter is a thin, disk-shaped glass or plexiglass camera accessory that is secured to the end of the camera lens. A filter controls which wavelengths of light enter the lens, just like the colored laboratory glasses worn while using the laser or Alternate Light Source (ALS). The most common filters used by crime scene technicians are *UV filters* and *polarizing filters*. UV filters block UV rays and protect the camera lens from scratches and dirt. Polarizing filters act

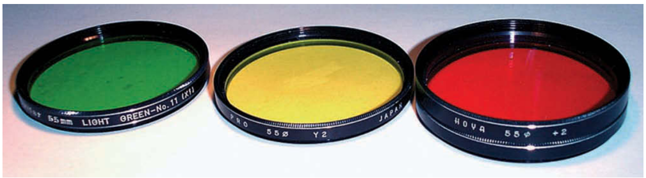


Figure 14.10 Green, yellow, and red colored filters.

like polarizing sunglasses. They remove glare in bright sunlight or when photographing reflective surfaces. *Infrared filters* and UV filters are used when photographing wounds on victims such as bite marks and bruising.

The most common filters used in fingerprint analysis are *colored filters*. A filter of a certain color blocks—or cancels out—that particular color in an image. This is especially helpful when a latent print is developed on patterned or colored backgrounds that make it difficult to see. For example, latent prints developed on bank checks are often difficult to see due to the patterned background of the check. More often, a colored filter is used to view luminescence when a fingerprint is developed with chemical reagents or fluorescent powders (Figure 14.10). The most common filter used in the forensic laboratory is the orange filter, since it is used to visualize and photograph indanedione, DFO, Rhodamine 6G, RAM, and several other fingerprint reagents.

Another accessory for fingerprint photography is the *latent print adapter (1:1 lens adapter)* (Figure 14.11). The adapter is a plexiglass tube that screws onto the lens just like a filter. The tube is placed over a latent print of interest. The camera autofocuses on the image and takes the photo (Figure 14.12). This is a fast and easy way to take quality, distortion-free photographs of latent prints after visible latent print processing techniques are utilized or at crime scenes.

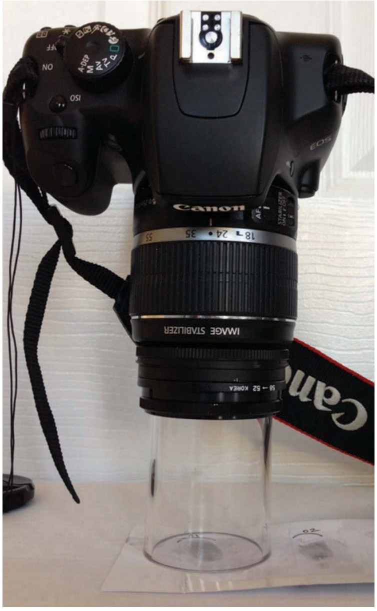


Figure 14.11 A 1:1 latent print adapter attached to the lens of a digital SLR camera.

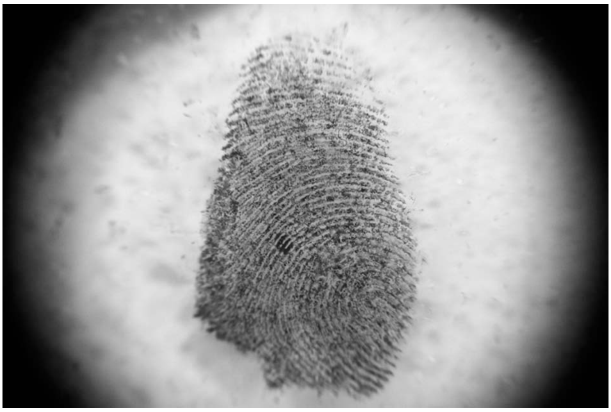


Figure 14.12 A photograph of a fingerprint taken with a 1:1 latent print adapter attached to a digital SLR camera.

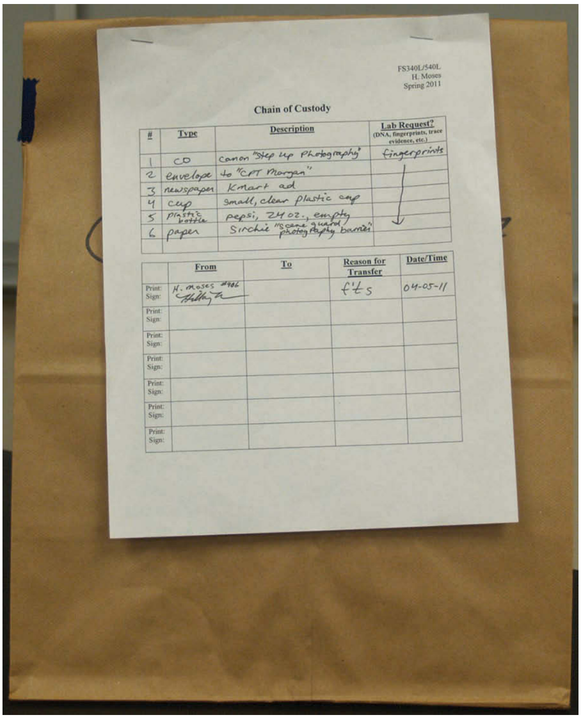
Regardless of the type of camera equipment or accessories used, the photographs must be accurate representations of the evidence. Photographs of latent prints will be used for latent print comparison purposes. Photographs of evidentiary items will serve as memory aids when writing a final report and testifying in court. They will also illustrate your processes and results for jurors, investigators, opposing forensic experts, attorneys, and any other individuals who must understand or analyze the case at hand.

14.4 Evidentiary Photography

Photographic documentation of latent print evidence begins when the evidence is received for processing. Each agency or department has its own SOPs for photographing evidence. What is presented here is an example of a thorough documentation process. If this process deviates from your department's SOPs, the author recommends following written departmental procedures.

When the evidence is received, and the chain of custody has been filled out, the sealed package is photographed (Figure 14.13). Any labels or identifying marks are documented and photographed. The evidence packaging may be a box, bag, or envelope. After the sealed package has been documented, the package is opened along a seam that has not previously been sealed with tape. If this is not possible due to the type of packaging or condition of the packaging or evidence, the seal can be broken in order to unseal the package and access the evidentiary items.

When the evidence is removed from the package, an overall photograph of the contents of the package is taken. In order to minimize distortion, the overall photograph should be taken at a 90° angle. The evidence is then photographed with a scale (a ruler or other graduated measuring device) and identifying information. If multiple items are present, the items can be photographed together, and then individually, with identifying information included in each photograph. Photographs of individual items should fill the camera's viewing frame. This is known as a *close-up photo*. Identifying information can be printed or handwritten on a card and should include the following information: case number, item number(s), fingerprint analyst's name or initials and ID number (if applicable), and the



FS340L/540L
H. Moses
Spring 2011

Chain of Custody

#	Type	Description	Lab Request? (DNA, fingerprints, trace evidence, etc.)
1	CD	canon "Step up Photography"	fingerprints
2	envelope	to "CPT Morgan"	↓
3	newspaper	Kmart ad	
4	cup	small, clear plastic cup	
5	plastic bottle	pepsi, 24 oz., empty	
6	paper	Sirchie "scene guard photography barrier"	

	From	To	Reason for Transfer	Date/Time
Print: Sign:	H. moses #906		f'ts	04-05-11
Print: Sign:				
Print: Sign:				
Print: Sign:				
Print: Sign:				
Print: Sign:				
Print: Sign:				

Figure 14.13 Photograph of a sealed evidence package containing several items of evidence with a chain of custody form attached.

date (Figure 14.14). The scale is used to determine the approximate size of the object. Many items are common objects that are of a known size: a soda can, a pen, or a sheet of paper for example; however, every item photographed must contain a scale.

The item is photographed close-up with the lens of the camera held parallel to the object to minimize distortion. A line drawn from your eye through the camera to the object must form a 90° angle to the plane of the evidence. This is best accomplished with a tripod. Distortion occurs in photographs when an object is photographed at an angle

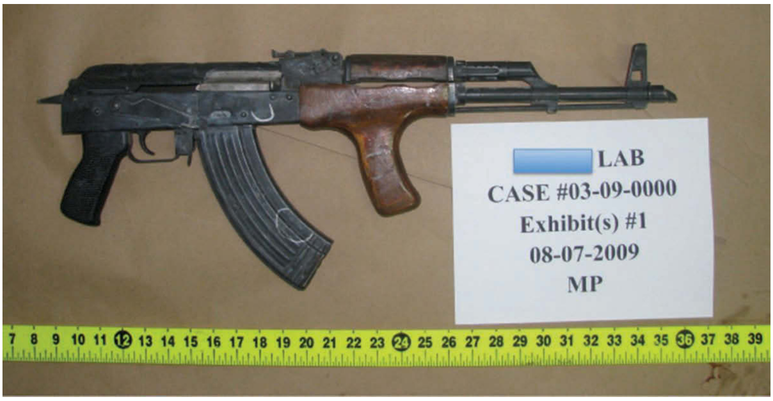


Figure 14.14 Close-up evidentiary photograph of an AK-47 type rifle with an identification card that includes the case number, item number, date, and the photographer's initials.

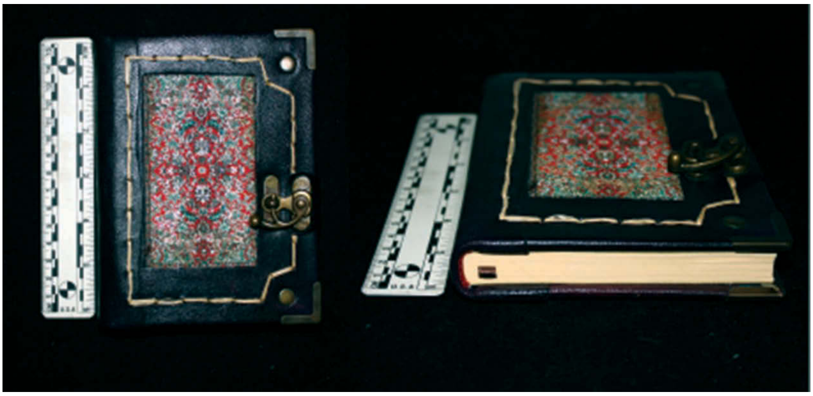

(a) (b)

Figure 14.15 An object photographed at a 90° angle (left) and an oblique angle (right).

(Figure 14.15). A distorted close-up photograph is not a true rendering of the evidence and is therefore not an accurate representation.

If the evidentiary item can be disassembled—such as a flashlight containing batteries—it should be photographed both before and after disassembly with a scale and identifying information. It is preferable to process any item of evidence prior to disassembly, especially if fingerprints on the exterior of the item may be damaged or obliterated during the disassembly process. For example, a fingerprint analyst may encounter a television remote with a removable battery. The battery cover must be removed in order to access the battery. If a latent print has been deposited on the back of the remote, it may span both the frame of the remote and the battery cover. If the cover is removed prior to processing, the latent print may be cut in half, smeared, or otherwise obliterated. Processing an item that must be disassembled can be accomplished in two "rounds." The first round of processing should be performed on the entire object, prior to its disassembly. Then, the item can be disassembled and processed again.

Once evidentiary items are photographed, they may be processed for latent prints. After each step in the processing sequence, all resulting friction ridge detail is photographed. Latent prints, whether visible or fluorescent, must be photographed with scale and identifying information, just as the evidence was photographed prior to processing. It is important to photograph the latent print parallel to the plane of the evidence, with a scale and identifying information. It is also preferable to fill the frame of the camera's viewer with the latent print in order to capture as much detail as possible. How the latent print is photographed depends on how it was processed and how it appears after each processing technique.

14.5 Photographic Lighting Techniques

There are four common lighting techniques used to document latent prints: *direct lighting, front directional lighting, backlighting*, and *oblique lighting*. There is no one correct way to photograph a fingerprint. The type of photographic technique selected depends on the processing technique, extent of development, background substrate, and amount of distortion.

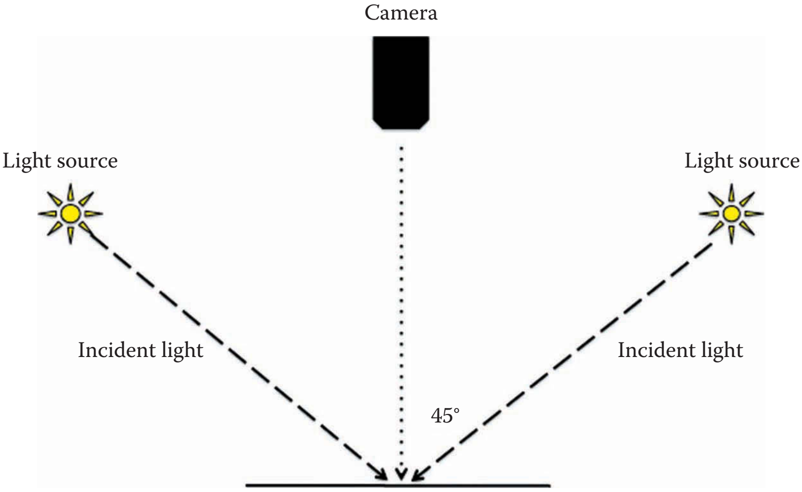


Figure 14.16 A schematic diagram demonstrating the direct lighting photographic technique.

Regardless of the lighting technique used, all friction ridge detail should be given unique identifiers and photographed with a scale. It is also recommended to photograph the entire area for context prior to performing any close-up photography, as the location and directionality of the latent prints may be critical to the interpretation of the forensic evidence. These are known as *evidence-establishing* or *mid-range photographs.*

For the *direct lighting* technique, the camera is mounted on a camera stand (copy stand) or tripod (Figure 14.16). The item with the latent print is placed on the stand or bench top, and the camera is focused on the latent print, filling the frame with the visible friction ridge detail. Two lights on arms mounted to either side of the camera stand shine light on the evidence at a 45° angle. This provides even illumination from both sides of the evidence. Direct lighting is best used when the fingerprints are visible on the surface. This includes patent prints, latent prints developed with ninhydrin or indanedione, or powdered prints. One method for capturing a high-resolution image of the visible friction ridges developed with ninhydrin or indanedione on two dimensional objects such as paper or cardboard is to scan the paper on a flatbed scanner set to 1000 ppi (pixels per square inch).

The direct lighting method is not useful on highly reflective substrates or on fluorescent fingerprints. Reflective objects such as mirrors or DVDs cause the light to reflect off the surface and enter the lens. The resulting photograph is too bright to capture friction ridge detail. Fluorescent fingerprints must be photographed under a forensic light source with the appropriate colored filter attached to the camera lens.

Visible fingerprints on reflective or concave objects—objects that curve inward such as cups or sunglass lenses—are best photographed with *front directional lighting* (Figure 14.17). For this lighting technique, the camera is mounted and the object is placed on a camera stand as with direct lighting. A sheet of plexiglass is held at an angle between the camera lens and the object. A single light source is used to shine incident light at an angle parallel to the plane of the lens and the substrate. Some of the light passes through the plexiglass and some reflects off the transparent sheet. This technique spreads out the light to indirectly illuminate the object, limiting the bright reflection caused by direct lighting.

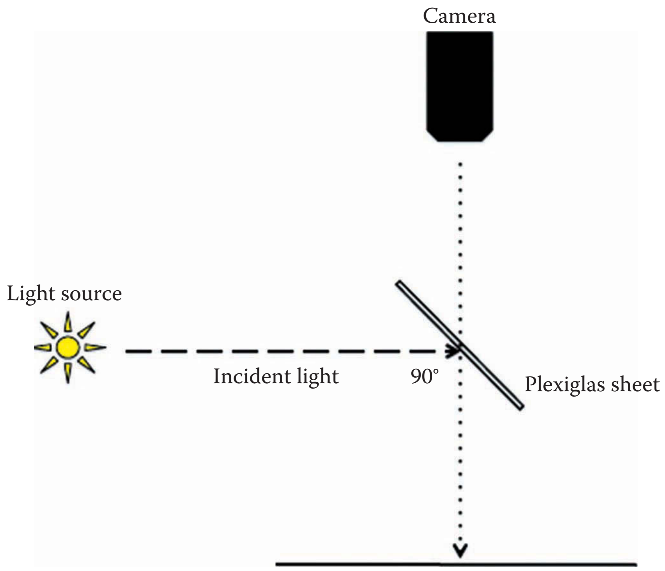

Camera
Light source
Incident light
90°
Plexiglas sheet

Figure 14.17 A schematic diagram demonstrating the front directional lighting photographic technique.

Latent prints on transparent objects such as glass, plastic, or clear tape are viewed and photographed most effectively with *backlighting* (Figure 14.18). To utilize this technique, the transparent item is placed on a light box, which shines light through the item from underneath. The light box is often the most effective way to view visible friction ridges on transparent items.

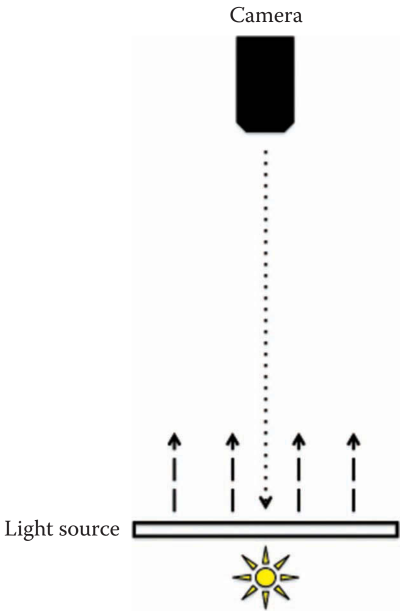

Camera
Light source

Figure 14.18 A schematic diagram demonstrating the back lighting photographic technique.

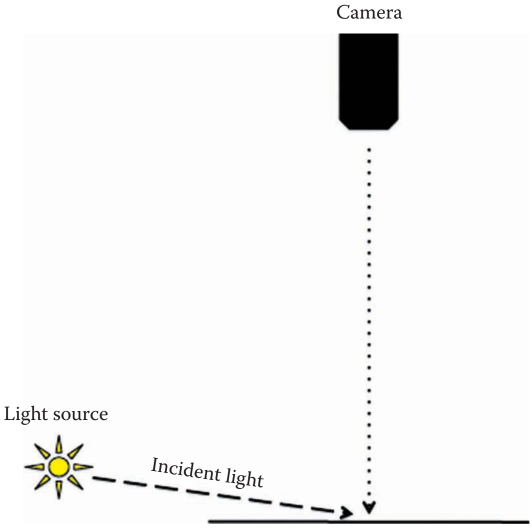


Figure 14.19 A schematic diagram demonstrating the oblique lighting photographic technique.

One of the most effective lighting techniques in fingerprint analysis (and throughout the forensic sciences) is *oblique lighting* (Figure 14.19). Oblique lighting can be used to view latent prints on objects during the initial stages of evidence processing. It can also be used to enhance three-dimensional details in evidentiary objects that have depth or height such as plastic prints, shoeprints and tire tracks, toolmarks, and wounds such as bite marks. Oblique lighting reveals details when light passes across the surface creating contrast with light and shadow. This can be accomplished on a camera stand by either lowering the arms holding the lights to the level of the camera stand table or holding a flashlight at various acute angles.

Oblique lighting is the best technique for documenting superglue-fumed prints since those prints tend to be three-dimensional. The three-dimensional nature of these prints is due to the fact that the cyanoacrylate (CA) polymer builds up on the friction ridges similar to blocks stacked one on top of the other. Superglue prints are also challenging to visualize and photograph due to their white or translucent color.

14.6 Troubleshooting Photography

As forensic photography can be challenging, it is susceptible to several common issues. These problems include photographs that lack identifying information or orientation, incomplete documentation, lack of camera control, and incorrect use of lighting.

A photo lacks identifying information when it is taken out of context or without a label. For example, a cartridge casing with a latent print may be one of many cartridge casings collected as evidence in a particular case. If the cartridge casing is not labeled in the photograph, it is unclear on which casing the latent print was found. Similarly, if there are 15 latent prints developed on a sheet of paper, each print must be labeled with scale and identifying information so that it can be distinguished from the 14 other latent prints on that sheet of paper, many of which may be similar in appearance.

In a photograph that lacks orientation, it may be difficult to determine which way is the "up direction" or where the print is located on the item. For example, consider a palm print found on a window during a burglary investigation. The window may have been opened either from the inside (by the homeowner) or from the outside (by the burglar). If the photograph only shows the palm print, and not where it is located or its directionality, the investigative value of that palm print is lost.

Lack of camera control can result in blurry or distorted photos. Always use a tripod if possible to limit camera control problems. Lighting problems occur when there is either too much light, causing overexposed, bright photos, or too little light, causing underexposed, dark photos. Both overexposed and underexposed photos make it difficult to observe and analyze detail. These issues can be minimized by practicing with the camera, reading the camera manual, and attending forensic photography training courses prior to conducting casework.

14.7 Uploading and Storing Photos

Every photograph taken is evidence in a case. Photographic evidence is admissible in court and as such is subject to analysis and scrutiny by a judge, attorneys, jurors, and opposing experts. Photographs are subject to *discovery*, meaning they must be made available to both the prosecution and defense prior to trial. For these reasons, no photo should ever be deleted, including those determined to be of no value. The sequence of photos, from the first photo of a case to the last photo of a case, should be unbroken. If a photograph is blurry, it should be retaken, not deleted. Deleting photos results in a break in the sequence. A defense attorney, judge, or jury may question why the photograph is missing, what the photograph represented, and whether or not the photograph was deleted because it may have exonerated the defendant.

Always take and save digital photographs in a lossless file format such as TIFF (.tif), RAW (.raw), or JPEG2000 (.jpx). "Lossy" file formats, such as JPEG (.jpg), should never be used to take or save photos. These file formats compress the image, resulting in some loss of detail. When photos are saved, they must be stored as "read-only" files so the originals cannot be manipulated. Regardless of whether the photographs are stored electronically or on storage media such as DVDs, these photographs are evidence and the chain of custody must be maintained.

Certain photographs may require enhancement in order to conduct an analysis. For example, latent print examiners routinely enhance photographic images of latent prints in order to perform latent print comparisons. Original images must never be manipulated. It is acceptable, however, to make a copy of the original image and enhance that copy. The copy should be clearly saved and named as a copy. The image copy can be manipulated using Adobe Photoshop® or other image enhancement software. When an image is enhanced for forensic purposes, the image enhancement software program should record a detailed history of each step in the enhancement process. Any individual with legitimate access to the original image should be able to make a copy of that image and duplicate the enhancement process to achieve the same results.

14.8 Final Reports

A final report is a summary of all the work done on a case, the results of forensic analyses completed, and the forensic expert's conclusion. A final report is written as a *narrative*; full sentences, in paragraph form. It is the last step in the documentation process, unless court demonstrations are created at a later date. Photos, worksheets, forms, and bench notes are used to write a detailed, thorough final report. In order to write an unbiased, scientific narrative of a case, the report must be:

- Objective
- Clear and concise
- Organized
- Thorough
- Unambiguous
- Well written (grammatically and stylistically)
- Written in accordance with your agency/department SOPs

A narrative is *objective* when it is not influenced by one's personal feelings or *biases*. Everyone has inherent biases or influences. Biases are based on life experiences, education, and values. As scientists, forensics professionals must push all personal and professional biases aside and examine the facts as objectively as possible. See Section 14.9 for more detail about the influences of bias in the forensic sciences.

A final report should be clear, concise, and unambiguous. When the content of your report is clear, any individual not associated with the case should be able to read, understand, and fully grasp the details of the case and your involvement with the investigation. Although there may be many details to cover in a final report, it must always be concise. Writing that is *concise* is as brief as possible without sacrificing content. If something can be described in either 100 words or 50 words, it is always preferable to cut the description down to 50 words. According to Strunk and White's *The Elements of Style*, an authoritative text on English composition and grammar, "Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts."[5] This is how a fingerprint examiner should approach the final report.

A final report is organized in a way that any investigator, lawyer, or juror who picks up the report should be able to understand the details of the case, the forensic scientist's actions, and the result of any analyses performed. The format of the final report may be specified in the department or agency's SOPs. Alternately, the final report may be submitted via report-writing software. Regardless of the format, the details of the case should be introduced first, then the actions described in chronological order, and finally the examiner's opinion and conclusions presented. One way to approach the narrative is to write in chronological order.

While the final report must be concise, it must also be thorough. It must describe in detail everything pertinent to the case. No detail, no matter how trivial it may seem, should be left out of the narrative. This includes any limitations of your analysis, which should be clearly stated. It is often difficult to predict what facts or analyses will become important, or even critical, to the case as the investigation unfolds. An item of evidence initially deemed insignificant might in fact turn out to be pivotal in an investigation.

Finally, a final report should be written in accordance with your agency or department SOPs. It may require a specific format or syntax. Agencies benefit from standardizing reports so anyone who reads a report originating from that agency will know where to find certain relevant pieces of information. If the reports are consistent in style and content, an investigator, police officer, attorney, or opposing expert can efficiently locate specific information or data.

A final report should be in *narrative* form. It is not meant to be a story, but a sequence of events related in paragraph form. The following are excerpts from actual final reports:

14.8.1 Excerpt: Fingerprints at Crime Scenes

Black fingerprint powder was used to examine the point of entry, point of exit, areas where items were disturbed, and items of evidence at the scene. Three latent prints (labeled L01, L02 and L03) were lifted from the door handle on the door leading from the main hallway of the home into the second bedroom at the northeast corner of the house. These latent prints were lifted onto standard latent lift cards. Elimination fingerprints were collected from the victim.

14.8.2 Excerpt: Laboratory Processing

On April 12, 2018, item #3, a serrated hunting knife with a black textured grip and an 8 in. blade, was removed from secure evidence storage at the Police Department Crime Laboratory in order to process it for latent prints. The item was documented comprehensively with photographs and notes. The item was then processed in the superglue fuming chamber, with positive results. Two latent prints were developed (L034 and L035). The latent prints were photographed with a Canon D-10 digital SLR camera.

On Sept 9, 2018, the evidence associated with case number 2018-00525 was transported to the Police Department Crime Laboratory for the purpose of latent print processing and comparison to the listed subjects. Following documentation of the initial condition of the evidence with notes and photographs, items #1–#12, #14, and #15 were processed for latent prints with visual examination, CA fuming, Rhodamine 6G, and magnetic fingerprint powder. All resulting latent prints were photographed for further analysis and comparison. Items #13 and #16 were processed for fingerprints using indanedione and ninhydrin. All resulting latent prints were photographed for further analysis and comparison.

14.8.3 Excerpt: Fingerprint Comparisons

The latent prints corresponding to case #2018-12345 were removed from secure storage at the Police Department Scientific Services Bureau in order to compare them with the listed suspects, victims, and witnesses. The comparisons were performed utilizing ACE-V methodology with the following results:

L001: ID—#2 finger of (s) Smith, John Q. (dob Jan 2, 1994)
L002: No value
L003: Exclusion—(s) Smith, John Q. (dob Jan 2, 1994)
L004: No value

"ID" indicates that it is this examiner's opinion that the latent print and the exemplar print likely originated from the same source.

"Exclusion" indicates that it is this examiner's opinion that the latent print and the exemplar print likely originated from different sources.

The more complex an examination is, the more documentation is required to support the conclusion. Thorough documentation leads to greater transparency and limits bias in any forensic investigation.

14.9 Bias

Bias is a concern in all the forensic sub-disciplines and is the subject of continuing research and interest throughout the law enforcement community. *Cognitive bias* is present in any human endeavor that relies on human decision-making.[6] The human brain has a natural tendency to form patterns and organize information in ways that are familiar. This is due to the human brain's propensity to make sense of the world around us.

Fingerprint examiners are concerned with two types of cognitive bias: confirmation bias and contextual bias. *Confirmation bias* occurs when the expected outcome influences the decision making process. The human mind tends to explain away discrepancies. For example, when a fingerprint examiner is comparing a latent fingerprint with an exemplar fingerprint, the examiner is looking for similar features between the two prints. If the examiner comes across one dissimilar feature between the two prints, he or she may try to explain away the dissimilarity as distortion or an artifact resulting from the chemical process used to develop the print. Similarly, if the latent print examiner sees a feature in the exemplar print, he or she may "see" the same feature in the latent print, even if it does not actually exist. This circular reasoning can be minimized by always analyzing the latent print before moving on to the comparison phase of ACE-V (Chapter 16).

Contextual bias is also a concern for fingerprint analysts. Contextual bias occurs when outside information influences the decision making process. There are several circumstances during which contextual bias might influence a latent print examiner. If the examiner has prior knowledge of the case, such as the identity of likely suspects, it could influence the examiner's decision-making process. Similarly, contextual bias may come into play if a detective shares his or her theory of the case.

Another possible source of bias occurs during the latent print verification phase of ACE-V. If the verifying examiner is aware of the results of the first examiner's analysis, if could influence the verifying examiner's decision. For example, if the original examiner identified the latent print to the suspect, the verifying examiner may be influenced by that conclusion and therefore more likely to identify the print to the suspect as well. Finally, the use of Automated Fingerprint Identification System (AFIS) is a source of bias that is becoming more problematic as the computer's search algorithms become more accurate. Extensive reliance on technology often results in close non-matches from AFISs to be identified erroneously by latent print examiners.

It is impossible to completely eliminate bias in any cognitive human endeavor. Sources of bias can, however, be avoided by limiting the examiner's access to contextual information.[6] Though, as Champod asserts, fingerprint examiners cannot operate in a vacuum.[7] Fingerprint examiners should thoroughly analyze all latent prints prior to comparing them with exemplar prints to eliminate the features in the exemplar print becoming a source of biasing information. The latent print verification phase should be a blind process, in which the verifier is not aware of the initial examiner's conclusions. Examiners should also educate themselves about sources of bias by reading the latest research and attending formal training courses on the subject of cognitive bias in the fingerprint sciences. Forensic scientists must be cognizant of all potential sources of personal or professional bias. Thorough documentation throughout every stage of a forensic analysis ensures transparency and limits the possibility of cognitive bias.

14.10 I Had a Case: Missiles in the Israeli Desert*

In some cases, it is not possible to transport evidence to a laboratory to process it for latent prints. This was the case for Israeli investigators when they discovered Dragon antitank missiles—stolen from an ammunitions depot—hidden in the desert (Figure 14.20). Moving the missiles to the laboratory for processing was ruled out for safety reasons. Instead, investigators built a mobile laboratory to process the missiles for latent prints in the field (Figure 14.21).

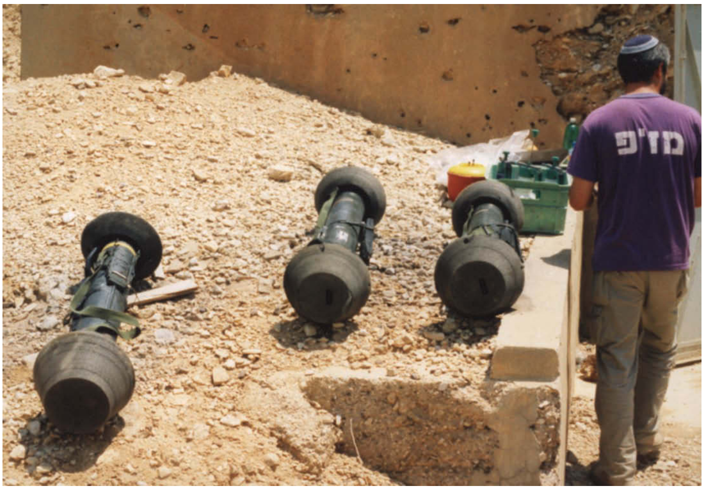


Figure 14.20 Dragon anti-tank missiles discovered under shrubbery in the Israeli desert. (Photograph courtesy of Eliot Springer.)

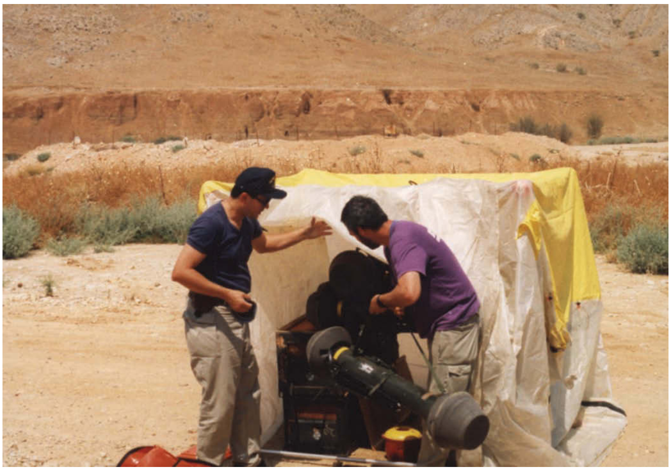


Figure 14.21 An improvised CA fuming chamber constructed to process antitank missiles at the site where they were discovered. (Photograph courtesy of Eliot Springer.)

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* [Submitted by Eliot Springer, Deputy Director, Police Laboratory, New York Police Department]

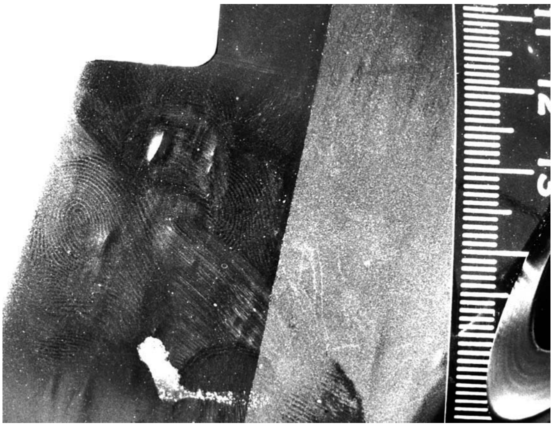

Figure 14.22 A photograph depicting the patent prints in dust/sand visualized on an antitank missile prior to sequential processing. (Photograph courtesy of Eliot Springer.)

Prior to processing the surface of the missiles for latent prints, a visual examination was conducted and one fingerprint in dust and sand was visible with oblique white light. The fingerprint was photographed extensively (Figure 14.22). Forensic investigators then carried out sequential processing methods using white light, an ALS, superglue fuming, dye staining, and a fingerprint powder suspension. The original fingerprint was destroyed in the subsequent development processes and no other latent prints were developed. The fingerprint in dust was entered into the AFIS and identified to a suspect. The suspect was arrested and consequently implicated an additional accomplice to the crime. Had the fingerprint not been found and thoroughly documented during a visual examination of the evidence, there would have been no forensic evidence linking the potential terrorists to the stolen missile.

14.11 Chapter Summary

Documentation of forensic processes includes extensive contemporaneous note taking; photography before, during, and after each process; the completion of forms, worksheets, and documents including a chain of custody; final narrative reports; and the preparation of visual aids such as charts or enhanced photos to use during courtroom testimony. Laboratory notes should include a detailed description of the evidence, steps taken to process the evidence, dates and times procedures were performed, and the results of each process.

Digital SLR cameras are used to photograph latent prints, evidentiary items, and crime scenes. Digital photography may require the use of a standard, multipurpose, or macro lens and a UV, infrared, polarizing, or colored filter. Direct lighting is best used with patent prints, ninhydrin and indanedione prints, and powdered prints. Front directional lighting is best used with latent prints on concave or reflective surfaces. Backlighting is used for transparent items. Oblique lighting is used for photographing three-dimensional evidence such as superglue prints or plastic prints. Digital photographs must be taken and saved in a lossless format. Only copies of images can be manipulated; never the original images. Photographs are evidence. A final report is an objective, clear, and concise narrative of all the work done on a case, results, and conclusions. Fingerprint analysts should be aware of personal and professional biases that could influence their analyses.

14.12 Review Questions

1. What are SOPs?
2. What details should be included in laboratory notes, and why should they be contemporaneous?
3. What is a chain of custody form?
4. What type of camera is most often used to photograph forensic evidence?
5. What is a filter? What are the four most common filters used by forensic scientists?
6. What photographic method is best for capturing fingerprints on transparent objects such as glass, plastic, or clear tape?
7. What fingerprint development technique is best photographed using oblique lighting?
8. What digital formats are unacceptable for recording and storing fingerprint images?
9. True or false. You should never make a digital copy of a latent print image. Explain your answer.
10. What types of bias may occur during the latent print examination process? Give examples of each.

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Crime Scene Processing

15

LEARNING OBJECTIVES

- Understand the peculiarities of crime scene processing.
- Recognize areas of interest for fingerprint processing in burglary, commercial, and vehicle scenes.
- Describe how DNA analysis and fingerprint analysis can both aid in the investigation of both violent and nonviolent crimes.

15.1 Crime Scene Investigation

Crime scene investigation (CSI) is a forensic analysis of the location and circumstances surrounding a crime. It comprises gathering investigative, forensic, and physical evidence to link a sequence of events, the goal of which is to reconstruct the crime scene. *Evidence* can be anything associated with a crime scene that may determine whether or not a crime occurred and establish innocence or guilt in a court of law.

A *crime scene* is the location where a crime took place. The primary crime scene is the location where the initial criminal act occurred. There may also be secondary or tertiary crime scenes. For example, if a victim is killed at a residence, transported, and dumped in a ditch by the side of a road, the primary crime scene is the residence; the secondary crime scene is the ditch where the body was dumped. If the vehicle is recovered, it becomes the tertiary crime scene.

A crime scene can be an unsafe environment. It is important to protect yourself from harm. Safety precautions should be taken when handling sharp items (broken glass, syringes, knives, etc.) or working around biological substances such as blood or semen. Gloves must be worn at all times. At scenes contaminated with biological fluids, it is beneficial to double glove (wear two pairs of nitrile or latex gloves). A particulate facemask and eye protection (laboratory glasses or goggles) can also be worn, along with disposable plastic coveralls and boot covers.

Regardless of the nature of the scene—whether it is a burglary, robbery, or homicide—latent prints serve an important function in CSI and reconstruction. Fingerprint examiners can identify likely suspects, victims, and associate an individual with an item of evidence. Recall the *evidence linkage triangle* (Figure 15.1) from Chapter 1, which indicates how latent prints can link a suspect to a crime scene, a suspect to a victim, and a victim to a crime scene. Most often, the crime scene investigator is interested in linking an individual to the crime scene either directly by associating latent prints from furniture or stationary structural elements or indirectly by identifying latent prints on evidentiary items.

Latent prints are compared with exemplar prints. Latent prints at crime scenes may not only belong to the suspect or victim; they also may belong to witnesses, family members,

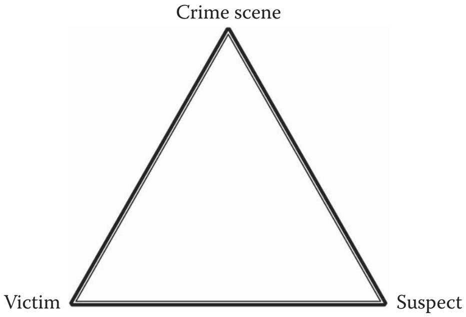


Figure 15.1 The evidence linkage triangle demonstrating the relationships between the crime scene, victim, and suspect. Latent print evidence can link the victim to the crime scene, the suspect to the crime scene, and/or the suspect to the victim.

bystanders, and normal commercial foot traffic in the vicinity. For example, if a bank is robbed, the *point of entry* (POE) is the front door of the bank. A crime scene investigator processes the glass doors and recovers 10 fingerprints and 15 palm prints. What are the chances the latent prints belong to the suspect versus the hundreds of patrons who frequent that bank? It is not possible to collect exemplar prints from every bank patron. In the case of a residential burglary, however, it is possible to collect exemplars from everyone who resides at, or has legitimate access to, the residence.

Exemplars from victims and witnesses are necessary in order to eliminate the latent prints that do not belong to the suspect. These are known as *elimination fingerprints*. Elimination fingerprints can be taken by using the ink or powder methods described in Chapter 5. The types of latent prints recovered at the scene determine the types of exemplars necessary to collect at the scene. For example, if latent palm prints are recovered, the crime scene investigator collects palm print exemplars and fingerprint exemplars from the victims and witnesses.

There are myriad situational factors that determine whether or not latent prints of value will be found at a scene. If the scene is located indoors, the cleanliness of surfaces of interest may affect the quality and quantity of latent prints recovered. If the scene is outdoors, environmental factors influence whether latent prints of value are preserved. Dry conditions, wind, rain, sun, and other weather effects may obliterate or deteriorate fingerprints. Latent prints may be preserved longer in humid conditions and in protected locations. It is important to remember that a lack of latent prints could indicate that the perpetrator either wore gloves or had dry hands.

Victims and witnesses watch crime dramas and often have unrealistic expectations of forensic practitioners. This is known as the “CSI effect.” The victim may want to know why you are not using a forensic light source, why you did not find fingerprints at the POE, or why you are not collecting DNA evidence. The crime scene investigator or fingerprint analyst can address these questions by politely explaining the actions taken. This is a good opportunity to educate a layperson about the science of fingerprints, as described in Chapter 19.

15.2 Crime Scene Kit

A fingerprint analyst working in a laboratory has access to chemical storage cabinets, laboratory glassware, benchtop workspace, and large equipment stored in a controlled

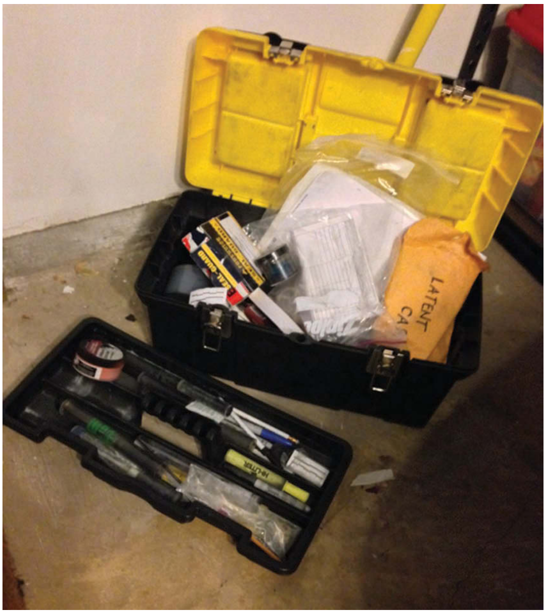


Figure 15.2 Crime scene kit.

environment. Conversely, the crime scene is an uncontrolled environment. All the equipment and supplies needed on the scene must be portable. Equipment is transported to the scene in a crime scene vehicle and carried into the scene by hand (Figure 15.2). The crime scene investigator utilizes tools of the trade that are particular to crime scene processing. The basic items are carried in a *crime scene kit* approximately the size of a tackle box. The following is a list of equipment and supplies necessary for documenting, processing, and handling latent prints at a crime scene:

- Gloves
- Writing implements
- Scales
- Magnifier
- Rubber/gel lifters
- Fingerprint powders (black, bichromatic, magnetic, and fluorescent)
- Fingerprint brushes (fiberglass, feather duster, and magnetic)
- Fingerprint lift tape (various widths)
- Latent lift cards (black and white)
- Silicone-based casting material
- Light sources (flashlight and forensic light sources)
- Camera equipment (camera body, lenses, filters, flashes, tripod, and 1:1 latent print adapter)
- Ink pad
- Tenprint cards or elimination print packet
- Handiprint System®
- Evidence packaging (paper bags, boxes, envelopes, etc.)
- Evidence packaging tape

15.3 Processing the Crime Scene

The first step to process a crime scene for latent prints is to conduct a thorough visual search of the surfaces and items of interest. The crime scene investigator focuses on areas and surfaces the suspect is likely to have interacted with. It is not necessary to process every smooth, clean surface for latent prints. Energy should be expended on surfaces relevant to the context of the scene, location, and type of crime. The following is a list of areas to focus on at the crime scene:

- POE
- Point of exit
- Areas of disturbance or items described by the victim or witness as out of place or moved
- Area where the crime took place, if known
- Ancillary areas such as bathrooms and kitchens
- The path the perpetrator may have taken through the scene (from the POE to disturbed areas to the point of exit)

Once the area of interest has been identified, a visual examination of the surface is the first step in fingerprint processing. Oblique lighting can be used to visualize latent prints that may not be clearly visible in daylight or direct white light. The best tool for visual examination is a flashlight. A flashlight held at oblique angles to the surface may reveal friction ridge detail (Figure 15.3). If latent prints are observed, they are photographed in situ (in place). Mid-range photographs are taken to show context. Close-up photographs can be taken with a 1:1 adapter or a macro lens. Plastic fingerprints are also photographed in situ. If the plastic print is durable, it can be cast with silicone casting material.

After all visible fingerprints are recorded, the surface is processed for latent prints using the appropriate processing technique. It is preferable to transport portable items of evidence to the forensics laboratory for processing and analysis in a controlled environment. Many texts suggest attempting chemical processing methods such as superglue fuming at the scene. This is not recommended for several reasons. First, chemicals and fumes present a hazard to health and property. Second, the laboratory is a controlled environment, leading to better quality results. Third, the chemical reagents available in the forensics laboratory are more sensitive and often result in more latent prints developed.

In order to assure the best quality latent prints are developed, evidentiary items must be packaged carefully so as not to damage latent prints. Items should be packaged in paper bags or envelopes. Packaging should be large enough that the item can be placed easily inside, but not too large resulting in the item shifting inside the package during transport. Sealed packages should be handled carefully by the edges so that latent prints are not inadvertently rubbed off.

The powder and brush method of fingerprint processing is the workhorse of crime scene fingerprint development. The technique, known colloquially as *dusting for prints*, seems simple; however, it takes practice to utilize this method effectively to develop latent prints of value. Because the fingerprint powder is brushed over the surface, it is possible to wipe away the latent prints rather than develop them. A gentle touch and attention to detail are required. The following methodology is suggested.

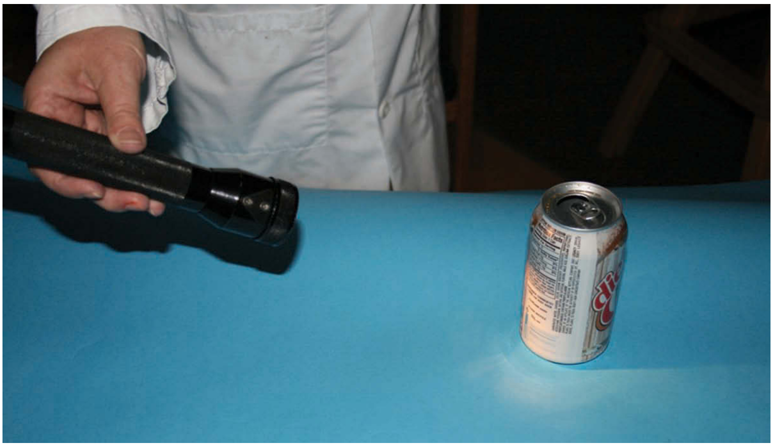


Figure 15.3 A forensic scientist examines an item of evidence using oblique lighting.

First, select a fingerprint powder. The color of the fingerprint powder should contrast with the color of the surface of interest. Black fingerprint powder is often the color of choice as it provides the best contrast on glass surfaces, light-colored glossy or painted surfaces, metal, plastic, and finished wood. Bi-chromatic fingerprint powder is effective on dark surfaces where the black powder is not easily visible. Magnetic powder is best suited for smaller areas where a gentler touch is warranted. Fluorescent powder is useful on patterned or multicolored surfaces as well as electronics but must be visualized with a forensic light source in a darkened room.

After selecting the appropriate fingerprint powder, pour a small amount onto a clean sheet of paper (Figure 15.4). This method is preferable to repeatedly dipping the brush into

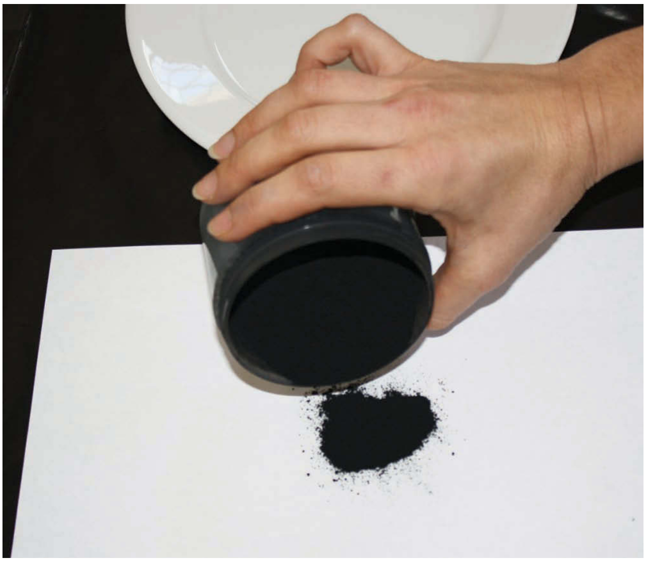


Figure 15.4 A small amount of black fingerprint powder is deposited on a sheet of white paper. This prevents cross-contamination between scenes.

the container of powder. It keeps the powder in the jar from becoming contaminated, dirty, or wet. Contamination is especially relevant due to the emergence of sensitive analytical methods for examining touch DNA. Next, remove a fiberglass brush from its protective tube. The brush fibers should not be tangled or contaminated with dirt other than fingerprint powder. A wet or dirty brush should be discarded in favor of a clean, dry brush. Twirl the brush to loosen the fibers. Gently tap the brush into the powder to pick up a small amount of fingerprint powder. Shake or twirl the brush to remove excess powder from the bristles (Figure 15.5).

Gently pass the brush over the surface. Be careful to only touch the surface with the tips of the bristles so that fragile latent prints are not inadvertently wiped away.

A very small amount of powder is all that is needed to identify areas with latent prints. When friction ridges begin to appear, concentrate your efforts on that area (Figure 15.6). Gently pass the brush over the area until good contrast and friction ridge detail are observed. Over-processing may result in accidentally obliterating the print. Work slowly and methodically. When the latent print is developed, it is photographed in situ with a scale.

After the latent print is documented, it is lifted onto a latent lift card. Choose a roll of latent lift tape of suitable size. If the impression is a palm print or a set of simultaneous impressions, a wider tape is used. Two-inch lift tape is commonly used for a latent fingerprint or small area of friction ridge detail. Pull enough tape from the roll to cover the area surrounding the latent print. Place the end of the tape on the surface next to the latent print. Sweep a finger down the length of the tape over the latent impression with a smooth, even motion (Figure 15.7). Rub the tape to remove any air bubbles and ensure the adhesive sticks to the entire area of the impression. In a smooth motion, holding both the roll and the loose end of the tape, pull the tape off the surface. Place the tape onto a latent lift card in the same way the tape was placed onto the substrate (Figure 15.8). Rub the tape to remove any air bubbles.

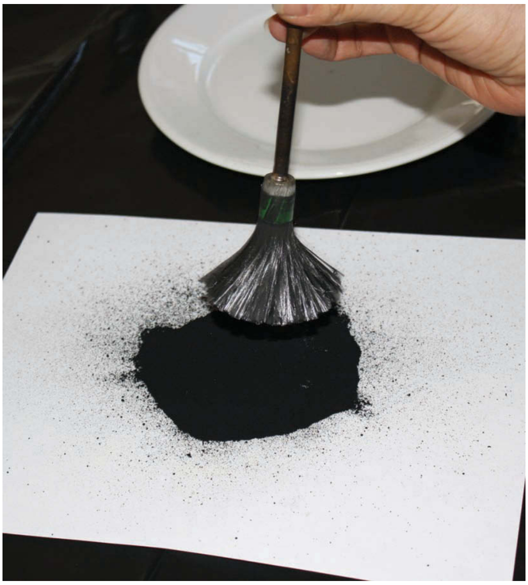


Figure 15.5 A fiberglass fingerprint brush is shaken to remove excess powder from the bristles.

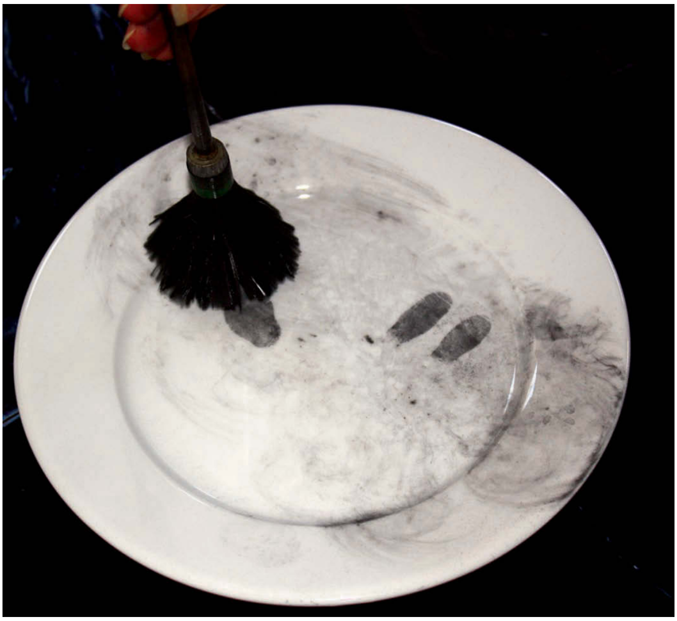


Figure 15.6 Latent prints are revealed as the fingerprint brush is gently passed over the surface of interest.

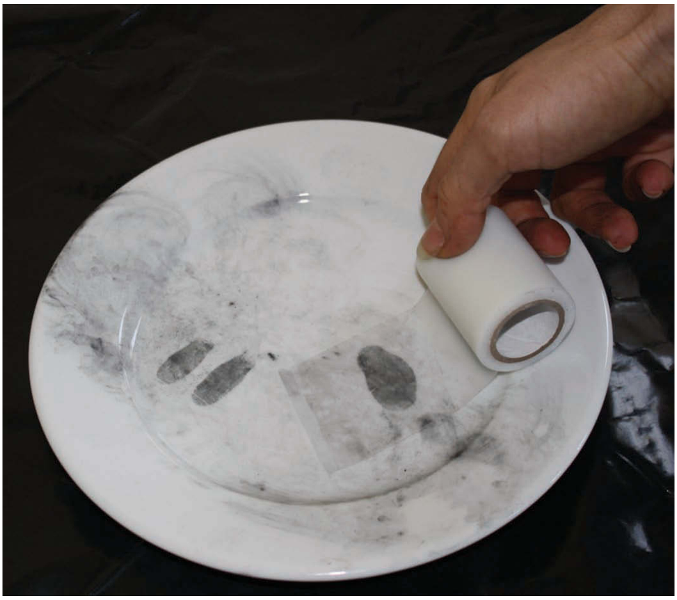


Figure 15.7 Latent lift tape is placed over the developed print.

Document the location and orientation of the latent print after it is mounted on the latent lift card. Indicate the up direction with an arrow on the front of the lift card (Figure 15.9). The latent print is given a unique identifier, such as L001 or #1. Sketch the location of the latent print in its original location on the back of the latent lift card (Figure 15.10), and indicate the

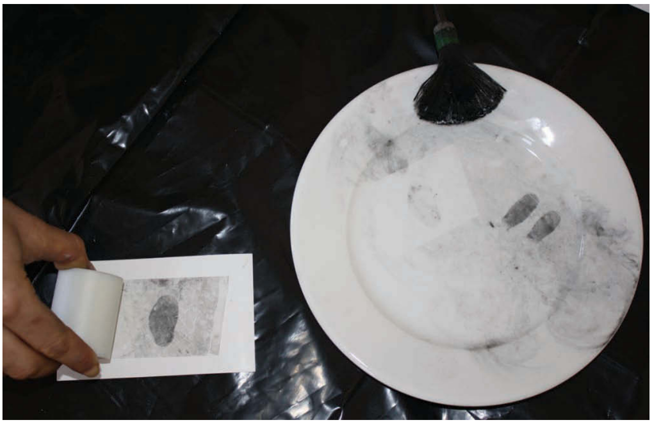


Figure 15.8 The latent print is lifted onto a latent lift card.

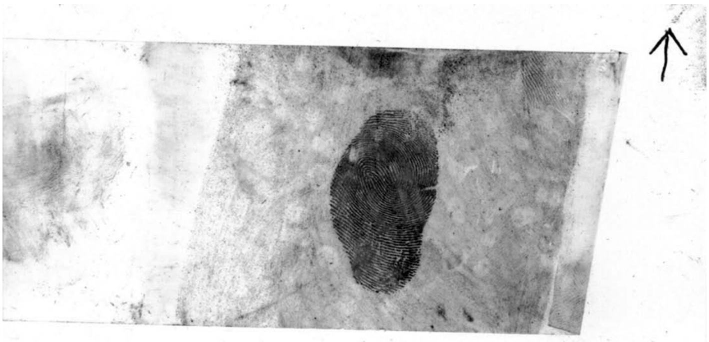
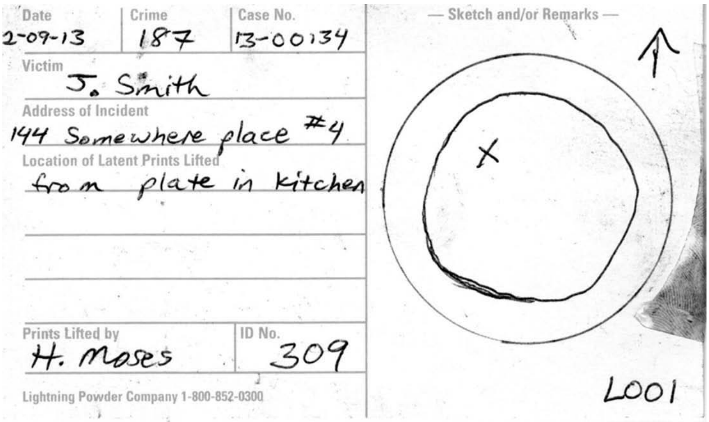


Figure 15.9 Orientation is indicated with an arrow on the front of the latent lift card. A corresponding arrow should be present on the sketch located on the reverse side of the latent lift card.



Date	Crime	Case No.
2-09-13	187	13-00134

Victim: J. Smith

Address of Incident: 144 Somewhere place #4

Location of Latent Prints Lifted: from plate in kitchen

Prints Lifted by	ID No.
H. Moses	309

Lightning Powder Company 1-800-852-0300

— Sketch and/or Remarks —

Figure 15.10 The date, crime type, case number, victim, address, location, examiner, examiner's identification number, sketch, latent print identifier, and orientation information are recorded on the back of the latent lift card.

up direction with an arrow. On many latent lift cards, there are preprinted spaces to fill in the following information:

- Sketch/diagram
- Case number
- Date
- Latent lift number
- Type of offense
- Victim/suspect
- Address/location
- Where the prints were lifted from
- Who lifted the prints (name, initials, and/or ID#)

Whether or not the information is printed on the card, it should be included for reference in as much detail as possible.

Documentation is important not only to record the case number and parties involved but also to provide context. The sketch and arrows provide context and orientation. It is often the *orientation*—the location and direction of the latent prints—that is a crucial piece of investigative evidence. Details of the examiner's actions at the crime scene are also documented in both note and narrative form as described in Chapter 14.

There are several common errors made by inexperienced practitioners when processing a crime scene for latent prints. The inexperienced examiner may load the brush with excess powder, thereby coating both the surface and the latent print residue with powder. Recall that fingerprint powder adheres to oil and moisture. If there is too much powder on the surface, there will be excessive background "noise." The goal is to develop a latent print that has contrast between the ridges and the furrows. Using too much fingerprint powder causes granules to be deposited between, as well as on, the ridges, thereby reducing or eliminating that contrast.

Another common error is when the practitioner is "heavy handed" with the fingerprint brush. Inexperience or impatience may cause the examiner to wipe the surface with the brush in long strokes, similar to painting a wall. This may wipe away latent prints or develop prints with drag marks through them. Skillful latent print development is gained through training, practice, and experience. All types of crimes, from auto-related offenses to homicides, may require the crime scene investigator to "dust for fingerprints". The following offenses are some of the most commonly encountered crimes requiring latent print development: burglary scenes, commercial scenes, and vehicular scenes.

15.4 Modus Operandi

The successful identification of a latent print is only the beginning of an investigation. A latent print identification provides the identity of subjects involved in a crime, but it does not tell investigators what took place, the timeline of the criminal act, or the motive behind the act. In the investigation of a crime scene, knowledge and understanding of human behavior are invaluable as clues to where to find the best physical evidence, including latent prints. The more an investigator understands about the how and why of a suspect's criminal actions, the easier it is to concentrate on those areas that will be most productive in the hunt for evidence.

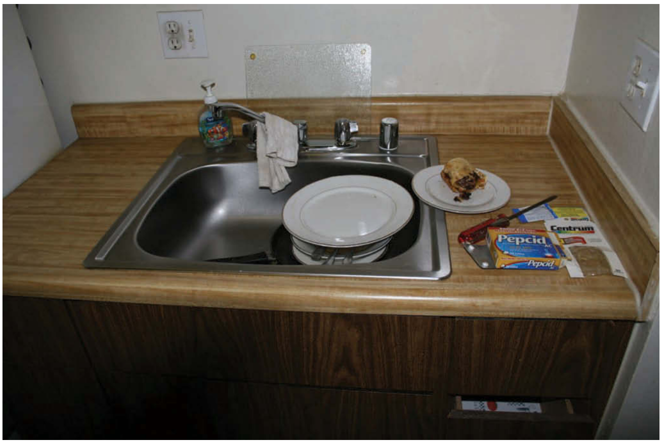


Figure 15.11 At this burglary crime scene, the suspect put down his screwdriver and made a sandwich. The suspect's fingerprints were found on the plate.

Much of a criminal's behavior is habitual, as is the case with all human endeavors. Certain burglars prefer certain entry points and particular methods of entering and searching a residence or commercial building. These habits are known as a criminal's *modus operandi* (MO), or method of operating.

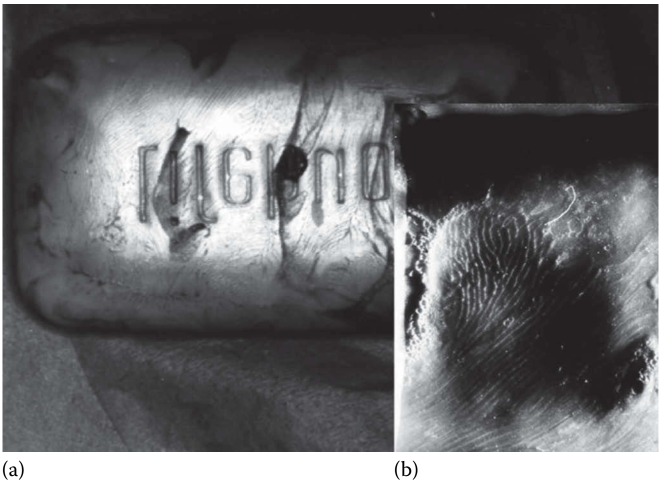
An experienced scene investigator can often propose a suspect or link multiple crimes to the same person by simply recognizing the criminal's MO. For example, suppose a series of residential burglaries in apartment buildings involves entry by use of pliers to twist open the doorknob on the front door. Once inside the apartments, the suspect goes directly to the master bedroom and removes the jewelry from the top dresser drawers. If and when a suspect is apprehended, knowledge of the burglar's MO can lead to solving similar burglaries.

Behavioral peculiarities may also lend a particular signature to the criminal's behavior. The burglar may go to the refrigerator and make a sandwich or open a beer and leave it on the counter (Figure 15.11). The burglar may use the bathroom or defecate on the living room floor; write a message on the wall; or pick up and look at family pictures. Peculiarities become habits that can assist in the identification and prosecution of an individual (Figure 15.12).

15.5 Burglary Scenes

Regardless of the type of crime, the setting or location will most often be one of the following: a residential scene, a commercial scene, or a vehicle. As mentioned earlier, a crime may involve multiple scenes. Each of these three settings presents challenges. The most common crime in a residential setting is a burglary. *Burglary* is the illegal entry of an individual into a building or vehicle with the intent to commit larceny or another crime. This is in contrast to a *robbery*, which is committed in the presence of the occupant and is a more serious crime.

No other crime has been more fruitful in terms of numbers of suspects identified by latent prints. As such, residential burglary is the primary and most important training ground for scene investigators. Residential burglary is also commonly the lesser-included



(a) (b)

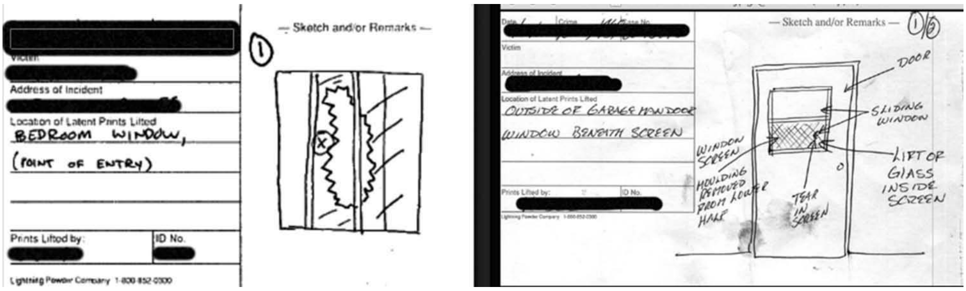
Figure 15.12 Enlargement (b) of a patent print on a bar of soap (a) identified to the suspect in a homicide.

offense in more serious (but far less common) offenses such as rapes and homicides. The more experience scene investigators have with common residential burglaries, the more qualified they become investigating more serious crimes in that same setting.

There are several hallmarks to a residential burglary scene. Access to a residential scene is usually limited to residents and invitees. The presence of a foreign latent print is therefore incriminating. Elimination prints of the residents are usually easy to obtain. Points of entry are also generally less secure than commercial scenes and are composed of house-grade double-hung or sliding windows and wooden doors. Since this is a crime of stealth on private property, eyewitnesses are also rare. The environment at a residential burglary scene is often rich in surfaces handled by the suspect, resulting in an abundance of latent prints.

The most productive source for latent prints is generally the initial POE. Windows are far more productive than doors, because doors are often kicked or forced open, the wood grain on the door surface can obscure friction ridges, and door hardware is frequently handled in the same place and tends to build up a film of residue. Very few people wash or wipe clean their door handles. This same reasoning also applies to anything with a small surface area that is handled repeatedly in the same place every time: light switches, drawer pulls, window latches, telephone buttons, keyboard keys, and garage door buttons are examples of these areas. Keep in mind that every scene is unique and exceptions are always possible.

When examining a POE window in which the glass has not been broken, search all parts of the glazing (the windowpane) using a very bright flashlight. It is helpful to circle any latent prints visualized on the glass using a marker or grease pencil. It is also advantageous to identify each circled latent print with an alphanumerical designation (such as “L001” or “A”). In order to preserve the context of the latent prints identified on the window, photograph or sketch the window. When photographic documentation is complete, lift the latent prints making sure that the label designations are included on the lift; for example, if the latent is labeled “1” on the window, the lift card containing that latent print must designate it as “1” (Figure 15.13).



[redacted]

Victim

[redacted]

Address of Incident

[redacted]

Location of Latent Prints Lifted

BEDROOM WINDOW,

(POINT OF ENTRY)

Prints Lifted by: [redacted]

ID No. [redacted]

Lightning Powder Company 1-800-852-0300

— Sketch and/or Remarks —

①

Date / Crime Case No. [redacted]

Victim

Address of Incident

[redacted]

Location of Latent Prints Lifted

OUTSIDE OF GARAGE MAN DOOR

WINDOW BENEATH SCREEN

Prints Lifted by: [redacted]

ID No.

Lightning Powder Company 1-800-852-0300

— Sketch and/or Remarks —

①/②

Figure 15.13 The backs of two latent lift cards associated with latent print designations and sketches.

Latent prints on the exterior (outside) of a window can lead to the identification of a suspect; however, the crime of burglary must show entry with the intent to commit theft or another crime. A print on the outside of a window does not necessarily indicate that it was placed there at the time the crime was committed. Latent prints have been demonstrated to remain on window glass for months or even years, despite the influence of environmental factors. An "old" latent print may appear to be fresh even if it is not. For this reason, once latent prints have been discovered on the exterior of the window, it is imperative to process the interior glass, especially the interior window *casement* (the frame of the window). If the intruder removed a screen before entering the window, latent prints on the frame of the screen can indirectly establish the age of the print if it can be shown by its position that the latent could not have been placed while the screen was mounted (Figure 15.14).

Fortunately, the interior and exterior casements of most residential windows are painted with glossy enamel paint that is an excellent substrate for latent prints. Process the entire circumference of the interior window and casement. Again, use a marker to outline and sketch any latent prints that are found in the scene. It is these interior latent prints that will prove that entry, an element of the crime, was achieved (Figure 15.15).

A burglary in which window glass has been broken offers additional opportunities for forensic evidence collection. Once an intruder has broken a windowpane, the individual will often remove fragments of glass from the molding in order not to be cut when crawling or reaching in. No effort should be spared in retrieving these fragments. Fragments removed from the frame can be identified by their straight edges originating from the casement molding. While picking out these glass fragments, the suspect will often deposit

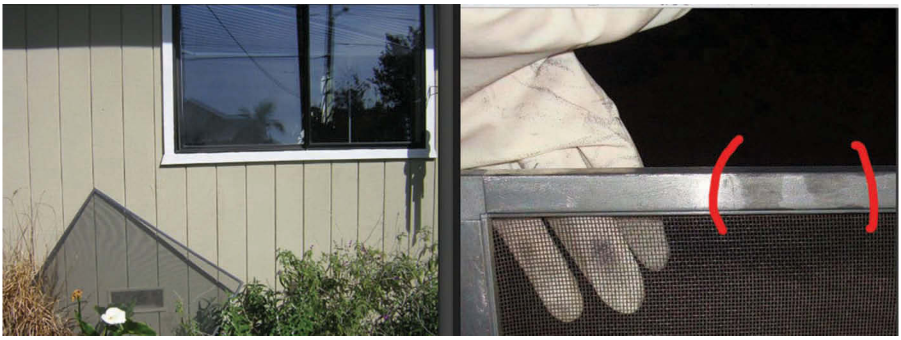


Figure 15.14 At this crime scene, the suspect removed the window screen to gain entry to a bedroom window. The latent print lifted from the frame was identified in AFIS.

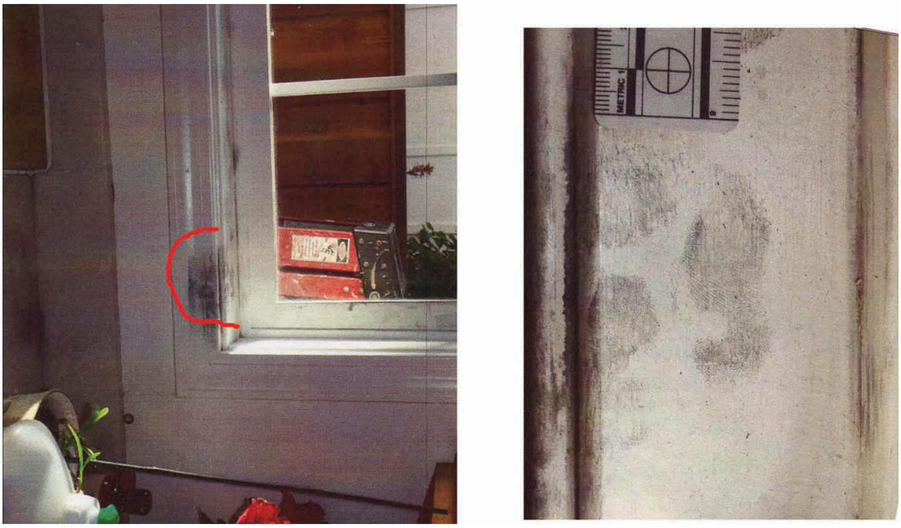


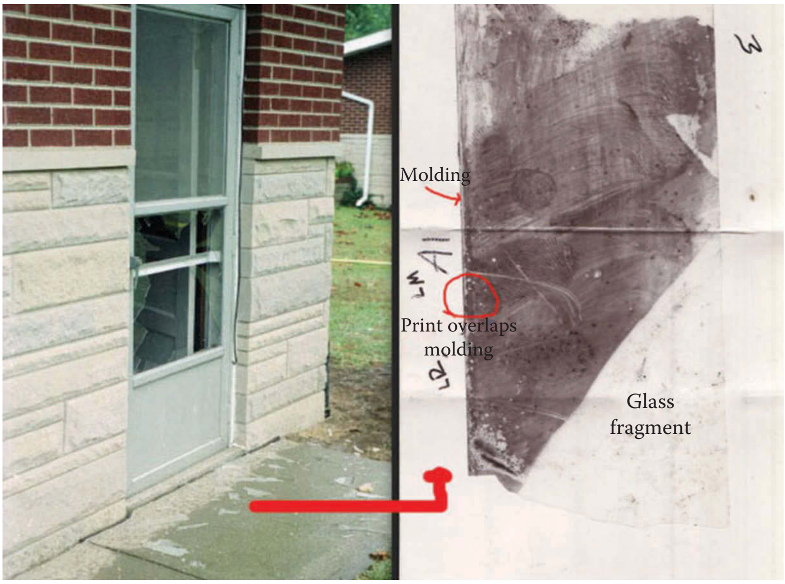
Figure 15.15 At this crime scene, the latent lift from the interior window casement resulted from the suspect reaching in with his right hand while climbing into the room.

a thumbprint on one side of the glass and an index and/or middle finger on the other side of the glass. The only time this could occur is after the window has been broken. It would be nearly impossible to observe this arrangement of latent prints on an intact window. Thus, from one fragment of glass, an examiner can demonstrate identity, entry, and time of deposit (since a homeowner or resident can testify to the window being intact at a certain time) (Figure 15.16).

When processing the interior of a residence, it is preferable to ask a resident for assistance. This individual will be able to point out exactly which items are out of place and which areas have been disturbed. Entertainment centers, desks, or tables that hold expensive electronics, such as televisions or computers, also often contain decorative items. In order to remove the electronic devices, the suspect may have handled decorative items around it. Picture frames, magazines, figurines, and DVD cases are all good sources for latent fingerprints. The top dresser drawers in the master bedroom are often ransacked for valuables. Jewelry boxes and small glossy boxes are often emptied and left behind. They, too, offer rich surfaces for latent fingerprint collection (Figure 15.17). Be aware that dirty or dusty surfaces may not reveal latent fingerprints, despite the resident's insistence that an item was handled or moved.

15.6 Commercial Scenes

Commercial scenes offer their own challenges for the forensic examiner. Commercial buildings are often open to the public and have an influx people during operating hours. Attempting to gather elimination prints is often a daunting task when these individuals are not available at the time of the investigation. In the case of a commercial burglary or robbery, the criminal often has a clear goal: usually money or merchandise. Consequently, there is less random searching, resulting in relatively fewer items to process. Eyewitnesses such as employees, customers, guards, and surveillance cameras are more common at



(a) (b)

Figure 15.16 Latent prints (right) lifted from glass fragments picked out of the molding (left) of a window.

commercial scenes. Another hallmark of the commercial scene is that the environment often consists of industrial surfaces and points of entry that are dirty, dusty, or otherwise not conducive to latent prints. Also, commercial scenes are difficult to preserve because the management is usually anxious to reopen for business.

The directed nature of the commercial burglary or robbery makes it fairly easy to focus on what items need to be processed for prints. Similar to residential scene investigations, a few observations are helpful for directing the commercial scene investigation. Cash registers are a challenge for latent print recovery. Buttons and levers are usually too soiled as they are handled many times per day and are seldom cleaned. Unless the entire register was picked up and moved, the most productive source of latent prints is the bottom of the

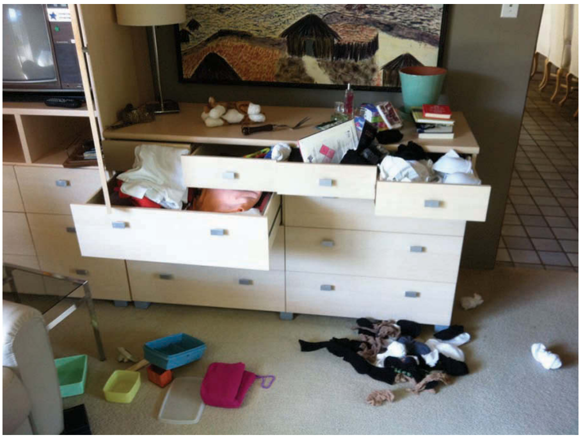


Figure 15.17 Typical ransacked dresser in the master bedroom of a burglary scene offering multiple surfaces for a latent print search.

cash tray insert. Best practices require that the plastic tray be taken to the laboratory and fumed with cyanoacrylate and other chemical reagents in a controlled environment.

Display cases in businesses opened to the public are usually cleaned frequently to better display the merchandise. Jewelry stores often clean the surfaces with glass cleaner several times a day. It is helpful if an employee or a surveillance video can pinpoint the precise area touched by the suspect. If latent prints are located, they should be indicated with a marking pen (similar to residential windows), diagrammed, and photographed before lifting. The location and orientation of latent prints on the display case can determine where the suspect was standing at the time of the crime.

In a robbery, the suspect often wanders the store picking up merchandise at random to assess his surroundings before approaching the cash register. Often, the individual will bring the items to the checkout counter, as if to make a purchase, and then abandon those items after the robbery is completed. If the item was from a cooler, it will soon be wet with condensation from the warmer store air. Latent prints can be developed on items such as these if the items are allowed to dry thoroughly prior to processing.

15.7 Vehicle Scenes

Vehicles are often used as either the tool or object of a crime. A vehicle can be a weapon, a means of criminal transport, a container for contraband (illegal items), or the target of a theft. Understanding some of the hallmarks of a vehicle scene can reveal investigative data that otherwise may be disregarded. Latent prints located on the exterior of a vehicle are often insufficient to support prosecution, because vehicles are mobile and operate on public streets. Even an identified latent print from an interior rearview mirror does not prove that the subject ever drove the car; it only demonstrates that the individual had at one time been in the car.

Another challenging aspect of vehicle crimes is that points of entry are often difficult to process. The windows of a vehicle are made of safety glass, which is manufactured to crumble on impact. Also, most surfaces within a vehicle are textured (dashboard, seats) or covered with a coating of dirt and grease that is the result of frequent handling (gearshift, buttons, steering wheel). Textured and dirty surfaces are not conducive to latent print development. Despite these limitations, crimes are solved every day from latent prints lifted from vehicles. The most productive sources for latent prints in a vehicle are windows, doorframes, rearview mirrors, and personal items found inside the vehicle.

15.8 DNA

In the United States, DNA has historically been an investigative tool in violent crime investigations such as homicides and sexual assaults. In Great Britain, however, DNA has been collected not only at violent crime scenes but also at property crimes, since 2000.[1] The British Home Office determined that although DNA is found only about 17% of the time, it generates a higher proportion of "matches" to suspects than latent prints alone.[1] A study conducted in the United States and published in 2008 found that DNA collected from property crimes resulted in twice as many suspect identifications as latent print evidence

(16% of suspects were identified through biological analyses versus 8% by latent prints).[1] Blood and saliva evidence yielded the most significant proportion of DNA versus touch DNA, which was not as successful. Touch DNA has emerged in recent years as the sensitivity of DNA technology has improved considerably.

Similar investigative considerations must be taken into account when collecting DNA evidence and latent print evidence at crime scenes. Roman et al. states:

> By following the steps burglars take in effecting their crimes, it is possible to determine the likely locations of DNA evidence at a crime scene. Residential burglars proceed through several steps, including generating a motive, target identification, entering the dwelling, searching the house, gathering items, leaving the house, and disposing of items.[1]

The POE and other areas described earlier are important targets for not only latent print evidence but also biological evidence.

Precautions must be taken if the scene investigator plans on recovering both biological and latent print evidence. Biological evidence is subject to contamination, cross contamination, and degradation. It must be collected and stored properly for future analysis. *Contamination* occurs when the biological evidence is corrupted by an outside source. For example, if a scene investigator breathes, sneezes, or coughs on an item of interest or touches an item with ungloved hands, the investigator's DNA may transfer to the item. *Cross contamination* may occur when two separate evidentiary items come into contact with each other. Biological evidence from one item may be transferred to the other item. For example, if a bloody knife is improperly packaged, some of the blood may transfer to other items of evidence. DNA is also subject to *degradation*, which is the breakdown of DNA in biological material over time due to exposure to chemicals such as bleach or environmental factors such as bacteria, heat, or sunlight.

The scene investigator can minimize contamination by wearing gloves and a particulate mask. Gloves should be changed frequently. Disposable fingerprint brushes and powders are available from forensic supply companies, although utilizing the processing technique described in Section 15.3 also limits contamination. Packaging items appropriately and drying wet items prior to transport minimizes cross-contamination. Degradation is avoided by collecting biological evidence samples prior to latent print processing. The samples or items should be stored in a cool, dry place until they can be transported to a laboratory or facility for controlled evidence storage.

Most law enforcement agencies do not routinely collect biological evidence at nonviolent crime scenes. For many, the process is cost and time prohibitive. DNA analysis is an expensive, time-consuming process. Many departments have backlogs of cases awaiting analysis. Many also do not have the funding to cope with expanding DNA laboratory capabilities, which would require hiring more analysts, investing in equipment and supplies, and possibly expanding facilities. Although not a common process to date, collecting both latent print and biological evidence (including touch DNA swabs) at nonviolent crime scenes leads to many more arrests and convictions than latent prints alone.

15.9 I Had a Case: Point of Entry

Crime scene investigators were dispatched to a burglary at a residence. The residence was a single family home that had recently been purchased by the victims. The POE was the bathroom window, which had been left unlocked. The perpetrator had removed the window screen and placed a patio chair beneath the window in order to gain entrance to the residence. He then climbed through the window, over the toilet, and into the bathroom. The interior bathroom window casement was processed with black fingerprint powder. Six fingerprints corresponding with the index, middle, and ring fingers of the right and left hands were recovered on the interior portion of the windowsill. The fingerprints were oriented facing into the bathroom.

At trial, the defendant insisted the fingerprints were legitimately placed on the windowsill when he toured the house as a prospective buyer several months prior to the incident. The orientation of the fingerprints was the critical piece of evidence in this case to prove intent. A casual guest to a residence could not possibly touch a windowsill in the orientation in which the latent prints were found. The only way the latent prints could have been placed there would be if someone reached into the window from outside.

15.10 Chapter Summary

A CSI is the gathering of forensic, investigative, and physical evidence in order to determine the location and circumstances of a crime. The crime scene is an uncontrolled environment versus the forensic laboratory, which is a controlled environment. Crime scene investigators carry basic items for crime scene processing in a crime scene kit. When an area of interest is identified at a crime scene, it is visually inspected for fingerprints, processed with fingerprint powder, and documented. Portable items of evidence should be transported to the forensic laboratory for processing in a controlled environment. MO is habitual criminal behavior.

Burglaries are common residential felonies. The POE, especially the window, is a productive source for latent prints, as are disturbed areas such as items out of place, ransacked areas, and areas where items are missing. Commercial scenes are challenging because they are open to the public or have an influx of people during operating hours. These scenes often have a focused goal, such as money or goods. Cash register trays, display cases, or displaced merchandise may be potential sources of latent prints. A vehicle scene may be complicated because a vehicle can be a weapon, a means of criminal transport, a container for contraband, or the target of theft. The most productive sources for latent prints in vehicles are windows, doorframes, rearview mirrors, and personal items inside the vehicle. Latent prints and DNA can both be effective weapons for solving routine cases.

15.11 Review Questions

1. Define "crime scene investigation."
2. What is the purpose of collecting evidence?
3. Why is it important to take elimination exemplar prints from individuals who have legitimate access to the crime scene?
4. Are latent prints of value always found at a crime scene? Why, or why not?
5. Why is it preferable to collect items of evidence rather than processing them at the crime scene?

6. Define burglary and robbery.
7. What are the hallmarks of a residential scene?
8. What are the challenges faced when processing a vehicle scene?
9. What is the most productive source for latent prints at a burglary scene?
10. What are the precautions that must be taken if a scene investigator is planning on recovering DNA evidence from a scene?

Reference

1. Roman, J. et al. 2008. *The DNA Field Experiment: Cost-Effectiveness Analysis of the Use of DNA in the Investigation of High-Volume Crimes*. Washington, DC: Urban Institute, Justice Policy Center.

Fingerprint Comparisons

Analysis, Comparison, Evaluation, and Verification (ACE-V) Methodology

16

> The examiner makes a transition from insufficient knowledge, through doubt, to knowing and belief.
>
> **John Vanderkolk**[1]

LEARNING OBJECTIVES

- Understand the purpose of latent print comparisons.
- Explain the three possible conclusions to a latent print comparison and their implications.
- Explain the three levels of fingerprint detail and their role in comparisons.
- Describe ACE-V methodology.
- Explain the various forms of verification.

16.1 Fingerprint Comparisons

The purpose of developing latent prints—also known as *fingermarks* or traces—and collecting exemplar prints is to compare one to the other to determine whether they may come from a common source (i.e., whether or not the same person is the source of both the known print and the latent print). These are known as latent print comparisons. Exemplar prints are also compared with other exemplar prints to determine whether an individual has a prior fingerprint record and to determine identity. These are known as tenprint comparisons. Fingerprint comparisons—both latent print and tenprint—are accomplished by determining whether both prints share similar minutiae in similar locations and orientations. Fingerprint identification is possible due to the two premises of fingerprint analysis: friction ridges are both unique and persistent. Although this chapter focuses on latent print comparisons, the same theory and process applies to tenprint comparisons.

Latent prints are developed using powders or chemical reagents. They are documented either on latent lift cards or as digital photographs. Exemplar prints are recorded with powder or ink or as digital images in an Automated Fingerprint Identification System (AFIS) computer. How one proceeds with a fingerprint analysis depends on the circumstances surrounding the crime. If a suspect is identified, and the suspect's exemplar prints are available, the exemplars (suspect and elimination prints) are directly compared with the latent prints. If there are no suspects named in a crime, the latent prints can be first compared to any available elimination prints and then searched in the AFIS database. The purpose of searching the AFIS database is to identify a possible suspect if the suspect is unknown.

A latent print will never be an exact replica of another latent print or exemplar print from a single source. Even if an individual intentionally places his finger on the same surface multiple times, the latent prints will not look exactly the same when developed. The processing method, distortion (due to motion, deposition pressure, and the elasticity of skin), surface characteristics, and the amount of matrix on the friction ridges can all affect the way a latent print appears after it is developed (Chapter 6). Similarly, distortion affects the way an exemplar print looks on a tenprint card or computer screen. In order to compare a latent print to an exemplar print, the latent print examiner analyses all aspects of the prints: the pattern type, ridge count or whorl tracing, ridge flow, and, most importantly, the types and locations of minutiae along the friction ridges.

Comparing fingerprints is an exercise in pattern recognition. Some people are more adept than others at analyzing patterns. Some individuals can look at two seemingly identical images and quickly pick out the differences between them. An example is shown in Figure 16.1. There are six differences between the photo on the left and the photo on the right. Can you find the differences? (Figure 16.1). Now examine Figure 16.2. Which line is longer? In actuality, both lines are the same length. The successful latent print examiner is detail oriented and can perceive detail without succumbing to inherent biases imposed by the human mind.

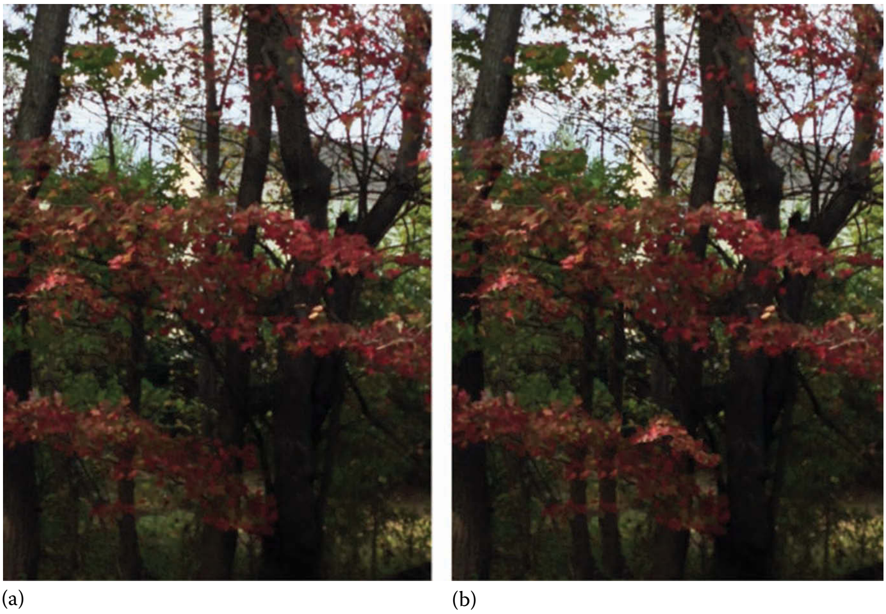


Figure 16.1 Find the six differences between the picture on the left and the picture on the right.

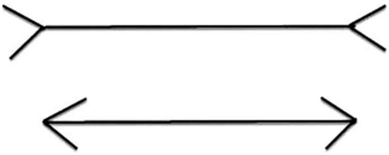


Figure 16.2 Human perception may lead one to believe the line on the top is longer than the one beneath it. The lines are, in fact, the same length.

16.2 Levels of Detail

Fingerprint examiners describe three levels of detail within a friction ridge impression. *Level one detail* refers to the overall ridge flow of the print. This includes the pattern type, shape, and the position of the core related to the delta, if both are present. While the examination of level one detail is an excellent place to start, under no circumstances can it be used to conclusively identify a latent print to a known source. For example, assume that the latent print is an ulnar loop with a ridge count of 16. The #3 finger of the suspect is also an ulnar loop with a ridge count of 16. Do these prints originate from the same source? Due to the high percentage of loop patterns in the general population, it is not unusual to observe fingerprints from different sources that have the same pattern type and ridge count.

A latent print examiner examines the level one detail to narrow down the possible source of the fingerprint. Continuing with the last example, if the suspect has 10 loops, but none of the loops have a ridge count of 16, the suspect is excluded as the source of the latent print. Alternately, the suspect may have 10 loops, but only two are ulnar loops with a ridge count of 16. The latent print examiner has now narrowed down the source to 2 possible fingers instead of 10. If the examiner were to look at every fingerprint of every suspect, witness, and victim with a magnifier without first examining the level one detail, it would take much longer than necessary to determine the source of the latent print. It is important to "see the forest for the trees" and work efficiently.

Level two detail refers to the minutiae within the pattern. An analysis of level two details includes not only the types of minutiae (e.g., ending ridges, dots, and bifurcations) but also the relative positions of the minutiae along the friction ridges (Figure 16.3). Where is the bifurcation in relation to the ending ridge? How many ridges separate the two minutiae? Is the ending ridge pointing up or down? Is the bifurcation pointing up or down? Is the ending ridge close to the bifurcation? Minutiae are examined with a magnifier. Unlike level one detail, level two detail may lead not only to an *exclusion* but also to an *identification*.

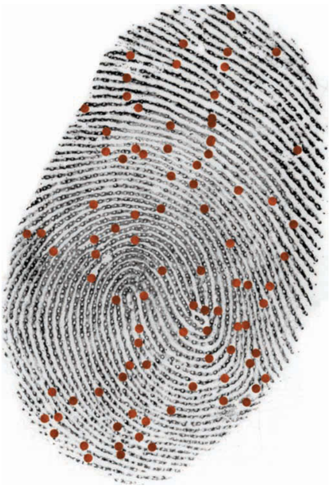


Figure 16.3 The minutiae in this double loop whorl fingerprint are denoted with red dots. The types of minutiae and their relative positions along the ridges are considered when examining level two detail.

Level three detail refers to the minute features and dimensions of the friction ridges themselves. It is an examination of the shapes, sizes, and relative positions of the pores along the ridge, as well as an examination of the edge shapes and widths (Figure 16.4). The study of level three details is known as *ridgeology*. Level three details are not always visible in latent or exemplar prints; however, when they are visible, they provide additional information to support a conclusion.

There are other features that may augment an analysis. Scars and creases often appear as straight, curved, or jagged white lines within a latent and exemplar print (Figure 16.5). Blisters, cuts, or warts may also be visible in a print, but these may heal and change shape over time. Level one, two, and three details are observed in a particular order based on the methodology fingerprint examiners employ to compare fingerprints. This methodology is commonly referred to as ACE-V: analysis, comparison, evaluation, and verification.

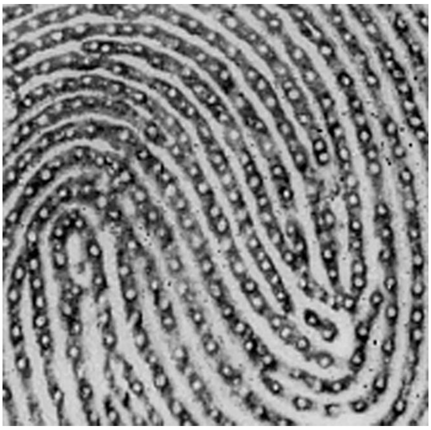


Figure 16.4 A double loop whorl fingerprint with edge shapes and pores demonstrating level three detail.

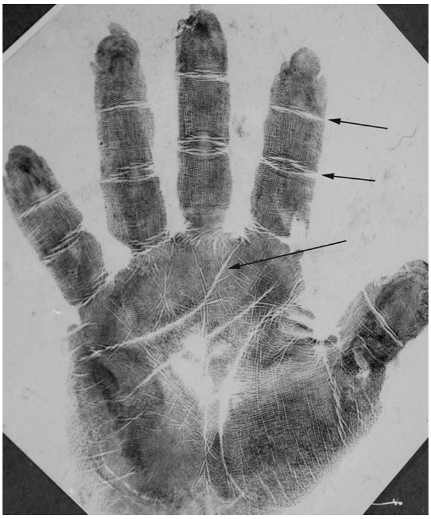


Figure 16.5 Arrows denote creases of the finger joints and palm.

16.3 ACE-V

ACE-V is a methodical analysis of level one, level two, and level three details in context. Regardless of the medium used to record the exemplar prints—ink, powder, or digital—fingerprint examiners use a process known as ACE-V to perform fingerprint comparisons. This methodology *standardizes* the comparison process to ensure that each fingerprint examiner follows the same steps to identify the source of a latent or exemplar fingerprint. The ACE-V process is not only used to identify the source of a fingerprint but also to exclude an individual as the source of the fingerprint. An *exclusion* conclusion is just as valuable as an *identification* conclusion.

ACE-V methodology was developed as an approximation of the scientific method in order to give the science legitimacy in the greater scientific community. The components of the scientific method are:

- Observation
- Hypothesis
- Experimentation
- Results
- Conclusion
- Peer review

ACE-V, although scientifically sound as a methodology, is not the scientific method. It was initially standardized by the Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST) in 2009 and revised in subsequent instructive documents.[2,3]

ACE-V is a systematic approach to analyzing a print and making a determination about its source. It follows a logical progression from an overall examination of the pattern to a more detailed examination of the minutiae and level three detail of the fingerprint. Vanderkolk describes the decision-making process as follows:

> The examiner transitions through the examination by analyzing, comparing, and evaluating the details of the prints through critical and objective comparative measurements of the details of general ridge flow, specific ridge paths and ridge path lengths, the sequences and configurations of ridge paths and their terminations, and the sequences and configurations of edges or textures and pore positions along ridge paths.
>
> The examiner makes a transition from insufficient knowledge, through doubt, to knowing and belief. The examiner bases this knowing on the previous training, experience, understanding, and judgments of self and a belief in the legitimacy of the training, experience, understanding and judgments of the collaborated community of scientists.[1]

The fingerprint examiner's final determination in the evaluation phase—identification, exclusion, or inconclusive—is the result of a quantitative and qualitative analyses of the prints. Quantitative analysis refers to countable data such as the ridge count, quantity of minutiae observed, and statistical data associated with a conclusion. Qualitative analysis refers to data that are not countable, such as the ridge flow, pattern type, and the quality of the prints. The fingerprint examiner's opinion is *subjective*, meaning the conclusion is based on the professional opinion of the examiner. A subjective opinion based on both qualitative and quantitative data is scientifically valid. The examiner's opinion is based on training, experience, and education.

16.4 Analysis

Analysis is the first phase of the ACE-V method. This phase is loosely analogous to the observation and hypothesis phases of the scientific method. The analysis phase involves an assessment of the overall features of the latent and known prints. It is tempting to immediately place a fingerprint magnifier (also known as a loupe) on the latent print to visualize the minutiae. This puts the examiner at a disadvantage, because the examiner is unable to observe the overall pattern and ridge flow at magnification. Analyzing the fingerprint at a distance allows the examiner to observe the shape and ridge flow of the fingerprint.

The analysis phase begins with a determination of *sufficiency* or suitability. In other words, is the print "good enough" to progress to subsequent steps. If the print is of poor quality, the examiner may choose not to analyze that fingerprint. It is therefore determined to be not sufficient for examination. This is also known as a "no value" conclusion.

Determination of sufficiency is a value judgment that varies with each individual. Research has found that sufficiency determinations increase with the number of quality minutiae in a print.[4] For example, if a latent print has six clear minutiae, one latent print examiner might determine that this print is sufficient, while another may conclude that it is of no value. If a latent print has 16 clear minutiae, it is likely that any latent print examiner would deem that print sufficient. Often a determination of sufficiency depends on the rarity of the minutiae observed, not just the quantity of minutiae present. For example, ending ridges are common in the delta of a print. A latent print with a delta and six ending ridges would not be distinctive, and perhaps not sufficient for comparison purposes. A latent print with a rare assortment of six minutiae—such as a spur, enclosure, crossover, or dot—would be much more unique, and therefore more likely to be deemed sufficient. If no suspect is listed for comparison, determine if the latent print is sufficient for an AFIS search. The threshold of sufficiency for AFIS is usually higher than the threshold of sufficiency for a comparison to a known suspect.

It is important to remember that even a latent print with few or no visible minutiae can be sufficient for comparison purposes if a pattern type is observed. A discernable pattern type can be used to eliminate a subject of interest. If the print is of sufficient quality to be compared to the exemplar, the examiner determines the pattern type, if possible. Once the pattern is determined, the examiner looks at the overall ridge flow, shape, and, if the fingerprint is a loop, the ridge-count of the loop. The anatomical area of origin is determined, if possible, as well as the proper orientation of the print (determining the "up" direction).

Once these observations are made, the examiner can then move on to a full analysis of the latent print, including the documentation of level two details and any observable distortion. This is completed prior to analyzing the exemplar print to avoid the influence of contextual bias (Chapter 14). Full transparency of the process is critical. Contemporaneous bench notes should indicate all observations discussed above. At this point, some agencies assign a level of complexity to the latent print in order to triage each case appropriately. Prints determined to be "complex" often require more documentation, and perhaps a second or third verification. Prints that are determined to be "easy" may not require as much documentation or attention.

Recent research has demonstrated that the quality of a latent print can be quantified—assigned a numerical value.[5] Computer software analyzes the number of pixels in color-coded areas of confidence to transform that data into a quantitative measure of quality.[5] For example, a clear, high-quality latent print can be color-coded green. If a latent print has an area of distortion, that area of distortion might be colored red. Areas of medium clarity can be colored yellow. The total area of green, yellow, or red pixels determines the latent print's quality "score." Higher scores (more green than red pixels) indicate higher confidence and greater clarity. Lower scores (more yellow and red pixels, and less green pixels) indicate lower confidence and less clarity. The objective, quantitative data provided by the computer can be incorporated into a statistical calculation to determine the strength of an identification, although no standardized statistical calculations exist as yet (Chapter 17). As with all procedures, your agency's standard operating procedures (SOPs) will govern your approach in determining sufficiency or complexity in a latent print.

Level two documentation—the marking of minutiae—is accomplished most often using computer software. Specialized forensics software can be purchased, but most image enhancement programs can be easily modified to mark up a latent print. Many fingerprint examiners use red dots to indicate minutiae points in both the latent and exemplar. If a greater degree of transparency is warranted, a more thorough method of documentation can be employed.

One such method of thorough documentation is known as the GYRO system.[6] The GYRO acronym stands for the colored dots used to mark minutiae: green, yellow, red, and orange. The green, yellow, and red dots indicate high, medium, and low levels of confidence in minutiae points. For example, if you observe a clear bifurcation in a latent, that bifurcation is marked with a green dot. Conversely, if there is a possible ending ridge in an area of distortion, and you are not confident about the location or type of minutia point observed, it is marked with a red dot.

Orange dots are only added during the comparison phase of ACE-V. They indicate that a feature in the latent print was not observed in the analysis phase, but was later observed after the comparison phase had begun. This level of transparency diminishes the possibility of confirmation bias by what is commonly referred to as circular reasoning. Once the analysis phase and all accompanying documentation are complete, the examiner moves on to the comparison phase of ACE-V.

16.5 Comparison

The comparison phase of ACE-V is loosely analogous to the experimentation and results phases of the scientific method. It is the process of comparing fingerprints side-by-side under magnification or enlarged on a computer screen. The latent print is placed to the left of the known print to avoid potential bias. If one is accustomed to reading from left to right, it stands to reason the examiner will "read" the fingerprints from left to right. The examiner will look at the print on the left, identify a feature of interest, and compare that feature with the print on the right. If the known print is placed to the left of the latent, the examiner may see a particular minutia point of interest and believe a feature is also present in the latent when in fact it is not. That feature may be an artifact of distortion. The examiner may become influenced by what they observe in the known fingerprint, causing unintentional confirmation bias.

When the unknown and known prints are placed side by side for a manual comparison, a stand magnifier, known as a *loupe*, is used for magnification. Loupes are well suited to fingerprint comparisons because the examiner's hands are free to use fingerprint *pointers*. Pointers are metal implements resembling pens that have pointed tips. They serve as

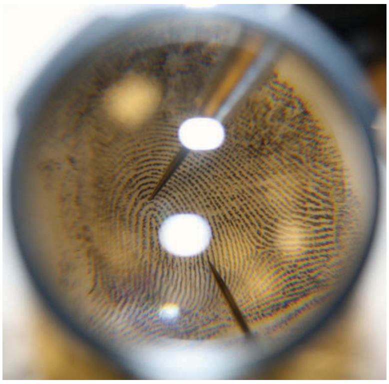


Figure 16.6 A loop fingerprint viewed through a magnifier. Pointers act as "place holders" when examining prints under magnification.

"placeholders" while the examiner compares minutiae in the unknown print to minutiae in the known print (Figure 16.6). When the comparison is to be completed on a computer, it is important to be sure the unknown print and known print are in the same orientation at the same magnification prior to proceeding with a comparison.

When the prints have been aligned in the proper orientation, the examiner then identifies a starting point, or target area, in the unknown print. The target area may be a core, a delta, or perhaps a distinctive cluster of minutiae. The area where the examiner begins is arbitrary and depends on personal preference and the nature of the unknown print. In a manual comparison, the pointer in the left hand is placed on a minutia point in the latent. The pointer in the right hand is then placed on the corresponding minutia point in the known print. The examiner can then move on to the next minutia in the unknown print and mark it with the left-hand pointer. The right-hand pointer moves to the corresponding minutia point in the known print. This process continues until the examiner is confident that he or she can come to a conclusion about the source of the unknown print.

A similar process is performed when the prints are compared on a computer screen. A target area is defined in the unknown print and located in the known print. The examiner marks each minutia point with a red dot or a color-coded designation (as with the GYRO method). The purpose of the comparison phase is to identify all similar points of comparison found in both prints in similar locations and orientations in order to determine whether they may have originated from the same source.

When the examiner has reached the point where he or she feels a determination can be made, the value of the marked features can be assessed. Less common features—spurs, short ridges, dots, crossovers, or unique core formations—are given more importance than more common features. Locations and orientations of minutiae are considered. When this process is completed, the examiner moves on to the evaluation phase of ACE-V.

16.6 Evaluation

The evaluation phase of ACE-V is loosely analogous to the conclusion phase of the scientific method. Utilizing the data gathered during the analysis and comparison phases, the examiner will conclude whether the unknown print and the exemplar likely originate from the same source. A comparison of two prints can lead to one of three conclusions: an *identification*, *exclusion*, or *inconclusive* result. This is a subjective determination based on the examiner's level of confidence with the quantity, quality, and rarity of all features in common between the latent and known prints.

An identification conclusion indicates that both the unknown print and the known print likely originated from the same source. For example, a latent print examiner may conclude that the latent print on the knife and the exemplar print from the suspect may have originated from the same source. SWGFAST has previously stated, "Individualization of an impression to one source is the decision that the likelihood the impression was made by another (different) source is so remote that it is considered as a practical impossibility."[3] Current doctrine has shifted away from declarations of absolute identity, because terms such as "practical impossibility" are not scientifically defensible. It is not appropriate to give the evidence more weight by implying a scientific certainty that may not exist. It is also unacceptable to assert a quantitative or statistical probability exists, unless one utilizes a probability model that has been validated and implemented at one's agency or department. For example, it is not possible to identify a print "to the exclusion of all others" or "with 100% confidence." It would be impossible to compare an unknown print to every other print on earth. There is room for error or exceptions in every scientific discipline. Similarly, terms such as "match," "identical," or "individualization" are no longer acceptable synonyms for "identification."

When an identification conclusion is reached, the final report should define "identification" so as to not overstate the value of the evidence to the investigator or the layperson (attorney, judge, or juror). Standardized nomenclature may render this necessity obsolete in the near future. Some agencies include standardized wording to describe an identification conclusion. Others refer to this conclusion as an "association" so as not to overstate the evidence. Here are some examples of acceptable statements that describe an identification conclusion:

- "There is sufficient correspondence of quality, quantity, and rarity of features to be confident that no other conclusion can be supported by the evidence."
- "I am of the opinion that the unknown and known fingerprints likely originated from the same source."
- "Given the specificity of the features and the size of the population considered, I would not expect to see this configuration of features repeated by random chance in another individual."[7]
- "An identification is effected when sufficient unique identifying characteristics are present in both the known and questioned impressions without any unexplained differences."[8]

There may be minor dissimilarities between the unknown print and the known print. If these dissimilarities are explainable, such as those caused by distortion or the presence of incipient (secondary) ridges, they should be thoroughly documented and explained. If there are unexplainable dissimilarities between the known impression and the latent print, the conclusion reached must be an exclusion. An exclusion indicates that the unknown print and the known print originated from different sources.

While erroneous identifications are given attention in the media, erroneous exclusions are far more common errors. An erroneous exclusion occurs when a fingerprint examiner determines that an unknown print and a known print originated from different sources when, in fact, no such determination can be made. The erroneous exclusion error rate is attributed partly to a lack of verification of exclusionary decisions.[9] Most agencies verify identifications, but not exclusions, inconclusive, or “no value” decisions.[9–11] Although Ray and Dechant suggest the implementation of 100% verification for exclusionary decisions, many agencies are unable to execute this verification standard due to large case loads or limited personnel.[9]

An inconclusive conclusion is reached if the fingerprint examiner is unable to come to an identification or exclusion decision. This conclusion is utilized if a determination cannot be reached due to a lack of sufficient data or detail. The latent print may not quite have enough information to make a conclusive determination, due to poor quality or insufficient minutiae. Similarly, the known print may not include the necessary area of interest, minutiae, or clarity to conduct a thorough comparison. For example, if the latent fingerprint is the left delta of a whorl pattern, and the exemplar fingerprint does not include the left delta, there may not be enough data to conduct a thorough comparison. This is why it is critical to collect comprehensive exemplars. The final stage of ACE-V methodology is the verification process.

16.7 Verification

The verification phase of ACE-V is analogous to the peer review phase of the scientific method. Verification is also referred to as “identity conformation.” It is a way to double-check the first examiner’s conclusion. During the verification stage, a second fingerprint examiner performs the ACE steps of ACE-V independently and reaches his or her own conclusion. Verification is essential to prevent errors. If an erroneous identification, exclusion, or inconclusive decision is made, an innocent person may be imprisoned, or a guilty person may go free. Either mistake is unacceptable. The verifier either supports or refutes the first examiner’s conclusions.

Verification can take two forms depending on the department or agency’s SOPs: non-blind verification or blind verification. At many agencies, the verifying examiner is aware of the conclusions reached by the initial examiner. This is non-blind verification. For example, the verifier will know that “L001” was identified to John Smith’s right index finger, but “L002” and “L003” were inconclusive. While this transparent style of verification is efficient—the verifier in our example will not waste time looking at every finger of every subject if he or she is aware that an identification was made to the right index finger—it is vulnerable to the effects of both contextual and confirmation biases.

Cognitive bias in the verification phase of ACE-V has led to several well-publicized erroneous identifications. Imagine that you are a relatively new latent print examiner who had recently completed your agency’s training program and started independent casework. A well-respected colleague with 30 years of experience has just asked you to verify a latent print identification. You are aware that the latent print was identified to the right thumb of the suspect. The ridge flow is in agreement, there are six minutiae in common, but you see two clear dissimilarities between the latent and exemplar. Would you be confident enough to conclude that the latent print is an exclusion, even though a very experienced latent print examiner determined it was an identification? What if you stopped after analyzing the ridge flow and the six minutiae found in the comparison phase? Would you then have confirmed the initial examiner’s identification? What if you were overwhelmed with casework of your own, or it was nearing the end of your workday? What if you had a sick child at home and only had a few hours of sleep? Could any of these circumstances have biased your conclusion? In an ideal situation, the answer would be, unequivocally, "No." In a real world scenario of this type, several skilled examiners have made erroneous identifications due to the influences of these biasing factors.

In order to minimize bias in the verification phase of ACE-V, many researchers recommend *blind verification*. Blind verification is a completely independent review by a second competent examiner who does not have information about the first examiner's conclusions. The case is completely re-examined "from scratch." SWGFAST published a guideline for applying blind verification in casework.[12] 100% blind verification occurs when all unknown prints are re-examined, regardless of whether they were deemed no value, exclusions, identifications, or inconclusives.

Some researchers insist that blind verification is necessary for a scientifically rigorous examination, as it has been shown to decrease the error rates in latent print examination.[13] Blind verification has received support in the United States from SWGFAST, the National Academy of Sciences (NAS), the National Institute of Standards and Technology (NIST) Human Factors Committee, and the President's Council of Advisors on Science and Technology (PCAST).[12,14–16] However, other forensic scientists assert that some context is necessary for a proper peer review.[17] This contextual information could include documentation from the analysis and/or comparison stages of ACE-V. Triplett and Cooney state, "The main goal of peer review is to look at how a conclusion was arrived at, not merely to confirm the conclusion."[17]

Some agencies do not have the personnel to conduct 100% blind verifications. In this case, blind verifications of identifications can also be problematic, considering the verifier knows the print was identified and could therefore be biased toward an identification conclusion. Many agencies also simply have too large of a caseload to conduct 100% blind verifications. As with all methods and processes, it is critical to follow your agency or department's SOPs with regard to verification.

What happens if the verifier does not agree with the initial examiner's conclusion? In the past, the inference was that one examiner must be "right" while the other must be "wrong." A more current philosophy asserts that it is entirely possible, due to the subjective nature of the comparative sciences, for two examiners to disagree. When this occurs, conflict resolution procedures can be utilized to come to a consensus. An agency or department should have clear, written conflict resolution procedures in place. In the case that the comparison is more complex, it necessitates more quality assurance procedures such as a second or even a third verification.

During the conflict resolution process, all examiners involved in the case discuss the data used to come to a conclusion and share documentation from the analysis and comparison phases of ACE-V. Latent print examiners who disagree about the interpretation of data are frequently not using the same features to come to a conclusion. Even if each fingerprint examiner observes similar features, he or she may interpret these features differently. Nordby states, "Observation is not interpretation. Observation involves implicit reasoning, and is instant; it is a mental experience. Interpretation, on the other hand, involves explicit reasoning and deliberate thinking."[18] The interpretation in a given situation is influenced by past personal and professional experiences, the information received, and the examiner's expectations.[18] The human mind seeks to form patterns based on the visual data it receives.[18] Figure 16.7 demonstrates how the brain interprets information based on data

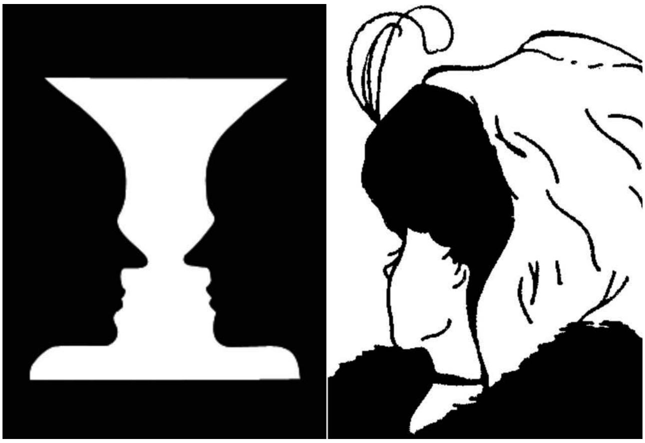


Figure 16.7 These optical illusions from the early 1900s demonstrate how the human brain interprets data based on expectations, prior experience and observations. The image on the left, the Rubin vase, can either be viewed as a white vase or as two faces in profile. The image on the right can either be viewed as a young woman looking over her shoulder or as the profile of an old woman.

and expectations. At the conclusion of conflict resolution procedures, a consensus should be reached that is acceptable to all parties involved.

16.8 I Had a Case: Conflict Resolution

In 1995, an elderly couple was murdered with a hunting knife while they slept in their beds. As the perpetrator exited the premises through the backyard, he tossed the knife over a fence into the neighbor's yard. Fingerprint examiners developed one latent print of value on the knife. This fingerprint was the only forensic evidence of investigative value in the case. The initial latent print examiner identified the latent print to the suspect. The verifying examiner, however, determined the latent print was inconclusive. A second verifying examiner reached an identification conclusion.

During the conflict resolution process, each examiner shared the documentation recorded during the analysis and comparison phases of ACE-V. They quickly realized that the first verifier incorrectly interpreted an area of distortion on the latent print. She assumed the additional friction ridges in that area of distortion, which contained several additional minutiae points, did not belong to the latent print. Once the conflict resolution was completed, all three examiners agreed to the identification conclusion. This latent print was critical evidence for obtaining a homicide conviction.

16.9 Chapter Summary

The purpose of latent print comparisons is to determine whether two prints originate from a common source. A comparison of two friction ridge impressions can lead to one of three conclusions: an exclusion, identification, or inconclusive. Level one, two, and three details are used to describe the features of fingerprints. Level one detail is the overall quality and ridge flow; for example, the pattern type, shape, core, and delta. Level two detail refers to friction ridge minutiae: the features or characteristics used for identification. Third level detail refers to the minute features of the friction ridge, including the shape, size, and position of pores and the edge shapes of ridges.

ACE-V methodology is used to compare unknown prints to exemplar prints. ACE-V stands for analysis, comparison, evaluation, and verification. Conclusions are based on a preponderance of qualitative and quantitative information in the latent print. The examiner effects an identification, exclusion, or inconclusive conclusion based on experience, training, and education. Blind verification is recommended as a method to reduce the influence of bias.

16.10 Review Questions

1. What is the purpose of comparing a latent print to a known print?
2. What are the three possible conclusions of a fingerprint comparison?
3. Which level of detail—one, two, or three—can be used to make an identification conclusion?
4. What is level one detail?
5. What does ACE-V stand for?
6. What is ACE-V?
7. Which component of ACE-V involves making a conclusion as to the source of the print?
8. Why is the verification step necessary?
9. What is blind verification, and what are the advantages and disadvantages to this method?
10. True or false. A latent print examiner's conclusion and expert opinion are subjective.

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Fingerprint Comparisons

Point Counting, Error Rates, and Statistics

17

LEARNING OBJECTIVES

- Explain the implications of a minimum point standard for fingerprint comparisons.
- Learn about error rate research and the calculated error rates for fingerprint examinations.
- Understand the purpose of statistics and probability models in fingerprint analysis.

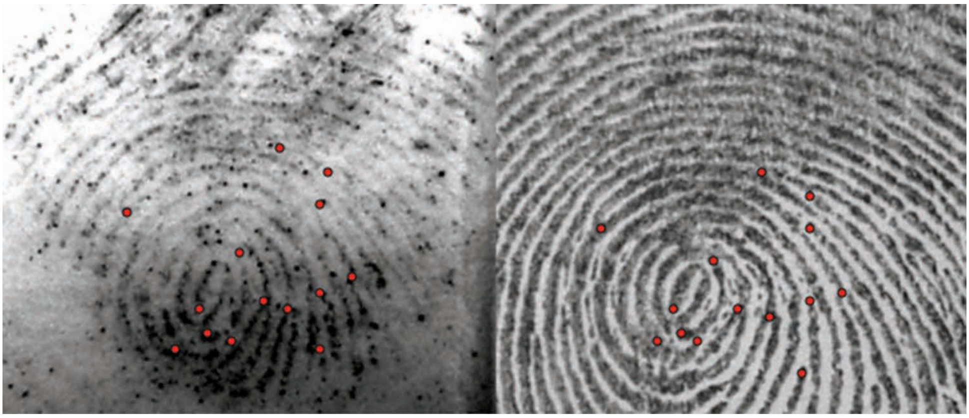
17.1 Identification Determinations

Fingerprint examiners utilize analysis, comparison, evaluation, and verification (ACE-V) methodology in order to determine whether two prints likely originated from the same source. Figure 17.1 is an example of a fingerprint comparison resulting in an identification conclusion. Ashbaugh summarizes the fingerprint comparison process with the following statement: “Friction ridge identification is established through the agreement of friction ridge formations, in sequence, having sufficient uniqueness to individualize.”[1] This statement can be broken down into the following elements:

- Minutiae and ridge flow must be similar in both the unknown and known prints.
- The minutiae must be found in the same general arrangement (location and directionality) in both prints.
- The ridge flow, minutiae, and distribution of minutiae must be unique enough to attribute them to one source.

In this case, “individualize” is synonymous with “identify,” although for some time there was an effort to utilize terminology that carried more weight with the scientific community. It was thought that the term individualize would imply that only one person could have been the source of both prints, and that all other exemplars in the world have been compared with that print.

As we cannot scientifically support such a claim of absolute uniqueness, there has been a paradigm shift toward transparency and scientific rigor. In a draft standard, the Friction Ridge Subcommittee from the United States’ Organization of Scientific Area Committees for Forensic Science (*OSAC*) states, “The friction ridge comparison discipline has experienced a shift from expressing the identification decision in absolute terms to expressing its findings as an expert opinion, based upon consideration of the evidence in terms of the support it offers to one of two competing propositions.”[2] The two competing propositions (hypotheses) are as follows:



(a) Latent print from water heater (b) Left thumb print

Figure 17.1 The image on the left is a latent print lifted from a water heater at a crime scene. The image on the right is the known left thumbprint of the suspect. The red dots denote minutiae in common between the two prints. The latent fingerprint (left) and the known fingerprint (right) likely originated from the same source.

- There is sufficient evidence to determine that the two prints originated from different sources
- There is sufficient evidence to determine that the two prints likely originated from the same source

This OSAC subcommittee is currently awaiting acceptance and publication of this document, which will provide guidance for utilizing ACE-V methodology, proper nomenclature for report writing, and articulation of results in the evaluation phase.[2]

17.2 How Many Points?

What constitutes "sufficient evidence"? How many features must you identify in order to come to an identification conclusion? How many minutiae must be found in common between the unknown and exemplar prints? How much is enough? Historically in the United States, *point standards* were imposed on the fingerprint examiner. One had to count at least 12, 14, or even 16 points in common, depending on the agency's standard operating procedures (SOPs), in order to effect an identification. Several countries retain a point standard today, although most have eliminated this practice.

Historical point counting originated from statistical research completed in the early 1900s. In 1914, a scientist named Edmund Locard used this research to come to the opinion that 12 or more points in common comprised a fingerprint identification; that 8 to 12 minutiae in common comprised a borderline comparison requiring more qualitative data; and that less than 8 minutiae could only provide limited source attribution information.[3] This is known at Locard's *tripartite rule*.[3] The tripartite rule was used as a basis for developing SOPs for point counting standards worldwide.

There is inherent fallacy in rigid point counting. Consider the situation where there may be a latent print of easy complexity with good contrast but only 6 points in common with the known print. Perhaps the latent and the known are both central pocket loop whorls with a distinctive scar through the core and a clear delta. Imagine also that both the latent and the known print share a distinctive, uncommon set of minutiae, such as a spur, dot, and crossover, and the third level detail and crease formations are also in agreement. There are many situations where the fingerprint examiner is confident about an identification that may not be the result of even 7 consistent minutiae. In contrast, there have been several documented situations in which two prints had 12 points in common, but were not in fact from the same source.

Instead of counting features, it is more realistic and accurate to take into account both the quantitative and qualitative features of the prints. Vanderkolk states, "For impressions from volar skin, as the quality of details in the print increases, the requirement for quality of details decreases. So, for clearer prints, fewer details are needed and for less clear prints, more details are needed. This follows the law of uniqueness in pattern formations in nature."[4] Thus, the fingerprint examiner bases a conclusion on a preponderance of both quantitative and qualitative data. It is up to the examiner to make an educated and thoughtful determination of source attribution.

In 1973, the International Association for Identification (IAI) established that there is no valid basis for requiring an identification to be based on counting a certain number of points. That position was further revised in 2009 to state, "There currently exists no scientific basis for requiring a minimum amount of corresponding friction ridge detail information between two impressions to arrive at an opinion of single source attribution."[5] An international declaration was proposed and signed by 11 countries at the International Symposium of Fingerprint Detection and Identification in Israel in 1995.[6] This position statement is known as the Ne'urim Declaration.

Figure 17.2 is a pictorial representation of this quantitative–qualitative threshold known as a *sufficiency graph*.[7] It represents the relationship between the quantitative and qualitative data observed during the analysis and comparison phases of ACE-V. A latent print that is high quality but contains few minutiae may not be deemed sufficient for comparison purposes. Similarly, a latent print that is complex and also contains few minutiae may not be deemed sufficient during the analysis phase.

The curves of the sufficiency graph are meant to be guidelines, not strict rules delineating what constitutes an identification or exclusion. Area "A," the red zone, is an area of low confidence.[7] It demonstrates that a latent print with a significant number of matching minutiae does not automatically result in an identification conclusion. The latent print in question may be unclear, distorted, or otherwise poor quality and not suitable to be identified conclusively to a source without an abundance of matching minutiae. Similarly, if a latent print is of high quality, the fingerprint examiner may require fewer minutiae to come to an identification conclusion.

Area "B," the yellow zone, is a figurative gray area.[7] Latent prints that fall into this area are often referred to as borderline or moderately complex. This is the area where the examiner may require more quantitative data to come to a conclusion. Area "C," the green zone, is an area of high confidence.[7] It represents the evaluation of a high-quality, clear latent print with an abundance of minutiae. Regardless of where the latent print falls on the spectrum, it is up to the latent print examiner to give a subjective opinion based on both qualitative and quantitative information.

In Europe, there are two different approaches to determining fingerprint source attribution. The holistic approach, also utilized in the United States and many countries outside Europe, bases a fingerprint source attribution on a balance of qualitative and quantitative

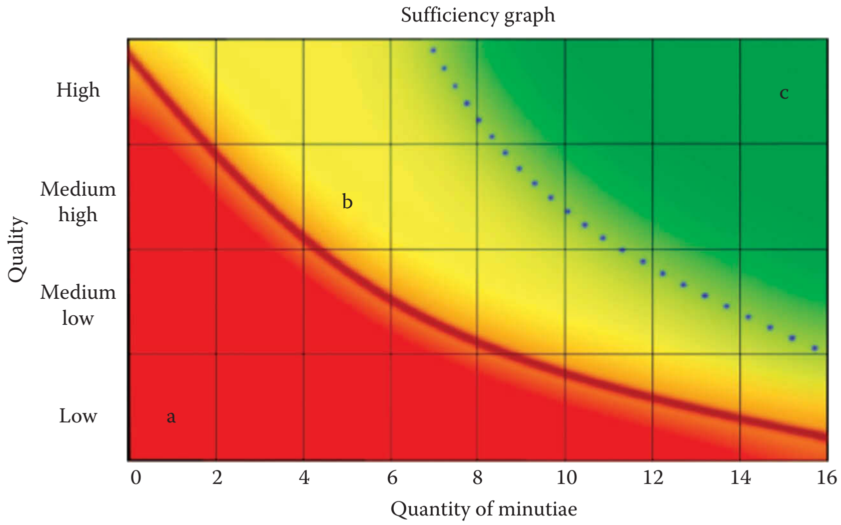


Figure 17.2 The sufficiency graph demonstrates how the fingerprint examiner weighs qualitative and quantitative data. The red zone (a) indicates a complex latent print with few minutiae. This zone is an area of low confidence. In the yellow area (b), qualitative and quantitative aspects of the fingerprint must be weighed to reach a conclusion, as the latent print is borderline in complexity. The green area (c) indicates clear latent prints with an abundance of qualitative and quantitative data. This zone represents an area of high confidence. (Reprinted from the Scientific Working Group on Friction Ridge Analysis, Study and Technology. *Standards for Examining Friction Ridge Impressions and Resulting Conclusions (Latent/Tenprint)*, Figure 1.)

data, as described above. The empirical standard, also known as the numerical approach, utilizes a point standard (most commonly 12 points) based on Locard's tripartite rule. However, this point standard is flexible as fewer minutiae can result in an identification if the quality of the latent print is high. A 2011 survey of 73 countries found that there were 44 countries with a point standard.[8] Half of those countries had a point standard of 12 or more minutiae, including Italy and several countries in South America.[8] The Czech Republic and Denmark had a 10 point standard, Bulgaria had an 8 point standard, and South Africa had a 7 point standard.[9] A review of the United Kingdom's 16 point standard in the 1990s resulted in a recommendation to abandon a point standard.[10] Australia abandoned the 12 point standard in 1999.[9] In contrast to the previous examples, China has a flexible 8–12 point standard that is dependent on the situation and quality of the latent print.[9] Ulery et al determined that the identification rate for examiners with a point standard was similar to the identification rate of examiners without a point standard.[11] The differences observed were not statistically significant. However, those with a point standard had a higher rate of identification.[11]

17.3 Error Rates

Even with stringent adherence to ACE-V, blind verification, quality assurance protocols, and conflict resolution procedures in place, it is still possible for errors to occur. NIST summarizes possible sources of error:

> Inadequate training, extraneous knowledge about the suspects in the case or other matters, poor judgment, health problems, limitations of vision, complex technology, and stress are but a few factors that can contribute to errors. A lack of standards or quality control, poor management, insufficient resources, and substandard working conditions constitute other potentially contributing factors.[11]

Errors are rare, but it is important to be aware of potential sources of error in order to avoid them wherever possible. *Error rates* are calculations indicating how often we would expect to see an erroneous conclusion, such as incorrect (erroneous) identification or exclusion. Error rates are necessary for the sake of transparency in a court of law and for the integrity of the scientific process. As a scientist it is crucial to communicate the limitations of ones findings. Error rates are one measure of these limitations of the forensic sciences.

Several landmark studies have explored fingerprint examiner error rates. In 2014, the Miami-Dade Police Department conducted a study on the reliability of the ACE-V process.[12] The first phase of the study examined the error rates of fingerprint examinations that were conducted using the "ACE" portion of ACE-V. The verification phase was left out of this initial study. A total of 109 latent print examiners conducted 4,536 latent print examinations.[12] The results of that study concluded that the error rate for erroneous identifications was 3%.[12] In other words, 3% of the fingerprint comparisons were determined to be identifications when, in fact, they were not identifications. Some of these errors appear to have been clerical.[12] For example, the examiner wrote down the wrong finger number such as a right thumb when he or she meant to record the left thumb.

The next phase of the research study added the verification step of the ACE-V method to the initial experiment. When verification was added to the process, no erroneous identifications were observed.[12] All errors were identified and corrected. The most surprising result of this study was the measured error rate for erroneous exclusions. An erroneous exclusion occurs when the fingerprint examiner determines two prints definitely do not come from the same source when in fact they do. The error rate for erroneous exclusions was found to be 7.5% when no verification step was conducted.[12] When the verification phase of ACE-V was added to the process, the erroneous exclusion rate decreased to 2.9%.[12] Only a little more than half of the erroneous exclusions were caught and corrected.

A more global set of studies, known as the "black box" and "white box" studies, delved deeper into the examination process in each phase of ACE-V. A *black box study* is a study in which data are input into a system, the resulting output is analyzed, but it is unclear how the system worked to generate that output. Imagine a black box. The box is opaque, so it is not possible to see the contents of the box. In this context, each fingerprint examiner—or more accurately, the brain of each fingerprint examiner—is the black box (Figure 17.3). The data provided to the examiner (or black box), which consists of sets of latent prints and exemplar prints, are known to the researcher. The conclusions reached by each examiner are likewise reported and are known to the researcher. What is not known, or hidden within the black box, is the examiner's internal decision-making process. What data were used to reach the reported conclusion? What was the basis of the conclusion? In a black box study, the emphasis is on the conclusion reached and not the decision-making process that led to that conclusion.

In the large-scale black box studies conducted by Ulery et al., 169 examiners compared 100 pairs of latent prints and exemplars and made a determination of identification, exclusion, or inconclusive.[13] The researchers found a 0.1% erroneous identification rate without a verification step.[13] It is assumed that these errors would be remedied during the

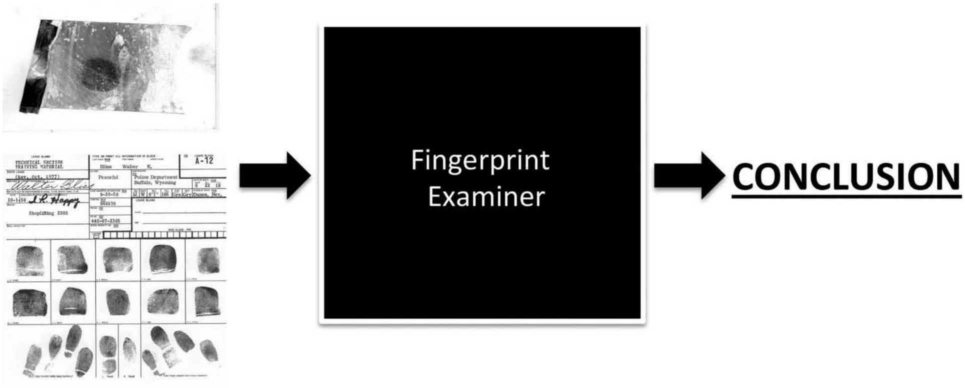


Figure 17.3 Diagram of the concept of a black box study. The fingerprint examiner uses ACE methodology to analyze, compare, and evaluate the latent print and exemplar. The purpose of the black box study is to examine the accuracy of the conclusion that results from the ACE methodology: identification, exclusion, or inconclusive.

verification phase of ACE-V. The erroneous exclusion rate was 7.5%, which is consistent with the Miami-Dade study described above in Section 17.3. The black box studies continued with repeatability and reproducibility studies. The repeatability studies explored whether a fingerprint examiner will come to the same conclusions about the same latent prints over time. The reproducibility study investigated whether different examiners would make the same decisions on the same latents. Ulery et al. found that repeatability and reproducibility were generally high, but were low for latent prints that were borderline or complex. In other words, latent print examiners were more accurate with their conclusions if the latent prints were easier. More difficult, borderline sufficient prints resulted in less accuracy.

Contrary to the goals of a black box study, a *white box study* is a method of research in which the internal workings of the process are examined (Figure 17.4). In this case, Ulery

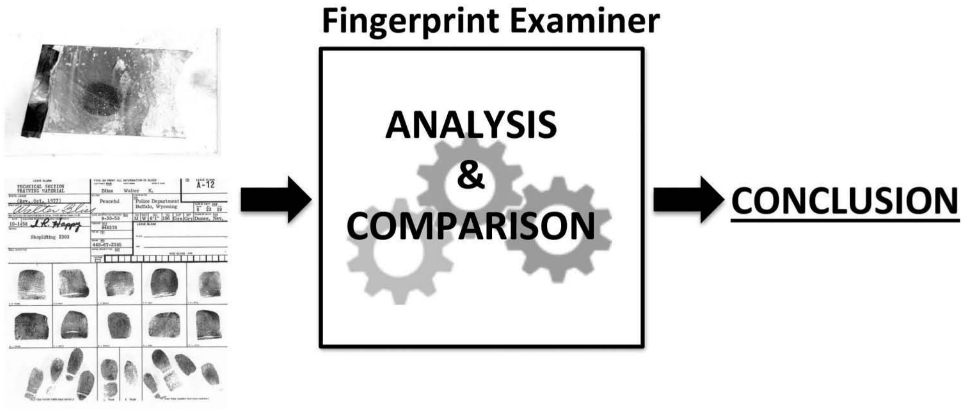


Figure 17.4 Diagram of the concept of a white box study. The purpose of the white box study is to examine the analysis and comparison phases of ACE-V methodology to determine how fingerprint examiners reach a conclusion.

et al. examined the analysis and comparison phases of ACE-V. Latent print examiners participating in the research study were asked to use color-coding to indicate areas of the latent print that were clear (green), moderate (yellow), or poor (red).[18] They were also asked to annotate minutiae and other features observed, such as cores, deltas, and pores. They analyzed the data and made a determination of sufficiency and complexity (very easy, easy, moderate, difficult, and very difficult) (Figure 17.5).

White box research projects are still ongoing at this time, with the following goals: understanding how latent print examiners make decisions; learning how best to document each phase of ACE-V; understanding how and when errors are made; developing methods to quantify or automate more of the ACE-V process; increasing transparency and comprehension for laypersons in a court of law. Future research into examiner error rates should focus on how to decrease erroneous exclusions, inter- and intra-examiner variation, bias, and the connections between the features observed and the conclusions reached. There are also efforts to standardize the application of the ACE-V method so that all fingerprint examiners apply it consistently.

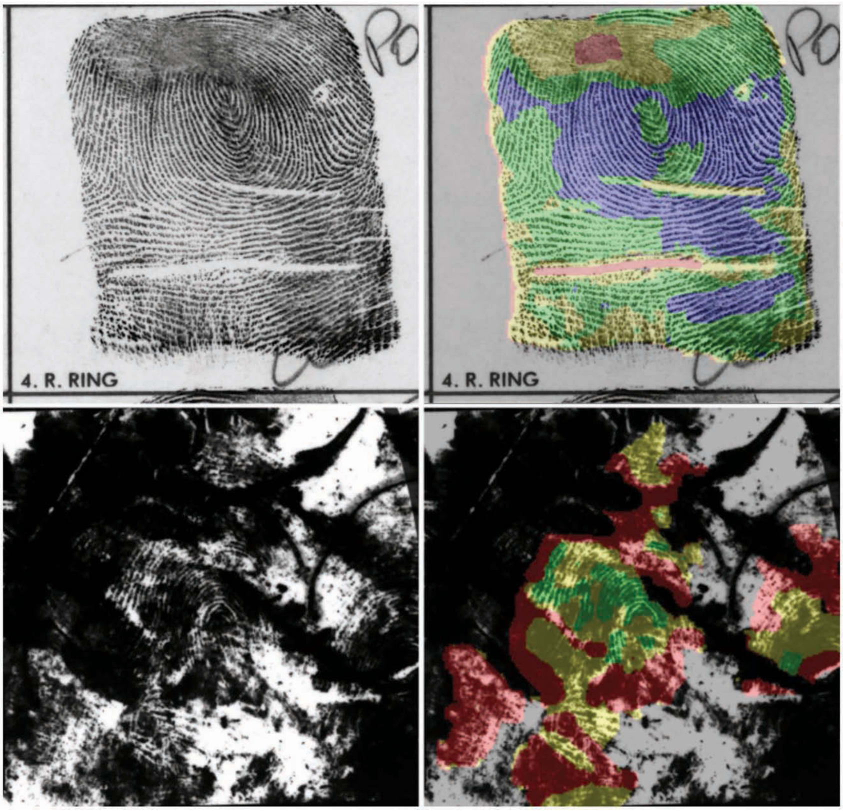


Figure 17.5 An example of color-coded clarity mapping for fingerprints of varying complexity: easy (top) and difficult (bottom). Blue indicates areas of clear ridge features. Green indicates areas of clear minutiae with undefined ridge edges. Yellow indicates areas of clear ridge flow but debatable minutiae. Red indicates areas of undefined ridge flow and a lack of minutiae. (Reprinted with permission from Hicklin, R. A., Buscaglia, J. and Roberts, M. A. Assessing the clarity of friction ridge impressions. *For. Sci. Int.* 2013, 226(2013) pg. 110.)

17.4 Statistics

In forensics, statistical models are used to quantify the strength of a conclusion. *Statistics* is a branch of mathematics that studies the probability of an event or series of events based on a given dataset. Probability is the inferred likelihood of an occurrence based on observable data from a specific population. A probability will generally fall between the values of "0" and "1." A value of "0" indicates that there is no chance something will occur in a given population. A value of "1" indicates a 100% chance of something occurring in a given population. If an event has a resulting probability of 0.8, you can expect that event to happen approximately 80% of the time.

Forensic biologists quantify DNA profile identifications using statistical models to demonstrate the strength of the evidence. These models are the result of decades of population studies that allow forensic biologists to infer that certain arrangements of DNA molecules happen in certain percentages of the population. For example, a certain allele (piece of DNA) may occur more or less frequently in a population of female Pacific Islanders than a population of Scandinavian males. Forensic statistics are thus more meaningful when the population is defined.

Historically, the fingerprint sciences have reported results and conclusions without including a quantifiable measure of confidence. Although it is neither inaccurate nor unacceptable to report these conclusions in court, it is more meaningful to present a measure of confidence in that conclusion. Would you have more confidence in reporting an identification based on a complex, borderline latent print with seven minutiae, or an "easy" latent print with 40 minutiae? Which identification conclusion would carry more weight in a court of law? As it stands, fingerprint examiners do not often distinguish these "borderline" identifications from easy identifications. They are both simply reported out as identifications. While the fingerprint examiner may be confident with both conclusions, it is prudent to quantify the strength of the source attribution in each case for the sake of transparency and clarity.

Over time, a fingerprint examiner looks at thousands of fingerprints and begins to form an opinion about the frequency of certain observable features. A loop pattern occurs with a much higher frequency than an accidental whorl. Similarly, certain minutiae occur more frequently than others. For instance, ending ridges are found in very high frequency around a delta. It would not be discriminating to locate five ending ridges in common between the delta of a latent print and the delta of an exemplar. As they are common features, ending ridges around a delta do not hold much weight. Other features are more rare, and therefore carry more weight as they occur less often in the population: such as crossovers, dots, short ridges, trifurcations, and spurs. When a fingerprint examiner observes these rare features in a latent print and an exemplar print, the identification is more compelling.

Some statistical models have addressed the need to quantify the strength of a conclusion based on the rarity of features observed and the frequency of these features in a given population.

What is the significance of the "given population"? Let's consider the following cases. Imagine a crime occurs on an airplane. A latent fingerprint is the only forensic evidence related to that crime. It would be a simple task to fingerprint all of the approximately 250 passengers and crew on the plane, and therefore identify the criminal. It would be straightforward to determine the statistical significance of the identification. What percentage of individuals on the airplane share the pattern type observed in the latent print? What is the frequency of each minutia point within that pattern? Plugging these values into a *probability model* results in a quantitative value of confidence.

Imagine instead that this crime occurred in New York City. The given population is much larger (approximately 8.5 million people). It would be impossible to compare that latent print to those of every New Yorker. In this case, a probability model can extrapolate the observable frequencies of features from a smaller sample population in order to infer the probable frequencies of features in a large population. If a dot formation is observed in 1% of a sample of exemplar fingerprints from 500 New Yorkers, and a dot is observed in the latent print, it can be inferred that the dot formation will occur in 1% of the population in question: in this case, New Yorkers. This is an example of a feature-based probability model. Other statistical models have utilized Automated Fingerprint Identification System (AFIS) technologies to calculate probabilities based on similarity scores.

Currently, there is no standardized probability model to calculate the strength of a fingerprint conclusion. Statistical models and probability theory have emerged in the fingerprint reference literature in the last decade, only a few of which are referenced here. Most of these probability studies were a direct result of criticisms of the comparative sciences by the United States' National Research Council (known colloquially as the *NAS Report*) and the President's Council of Advisors on Science and Technology (*PCAST*). Both documents recommended that the feature comparison methods of forensic analysis conduct research into developing statistical models.

Several probability models are currently in development, and a few are used in routine casework. The United States Department of Defense's forensics bureau, the Defense Forensics Science Center, uses a software program known as *FRStat* to quantify similarity.[28] FRStat quantifies how similar the minutiae configurations are between the unknown and exemplar prints. It is likely that several probability models will emerge in coming years and will be developed for routine casework.

17.5 I Had a Case: The Madrid Error

On March 11, 2004 terrorists bombed commuter trains in Madrid, Spain, in a coordinated attack now known in Spain as "11-M." Nearly 200 people were killed in the blasts and thousands were injured. Among the forensic evidence collected was a plastic bag containing detonators. The plastic bag was processed with cyanoacrylate fuming and a latent print was developed and photographed. On March 23, Interpol requested that the Federal Bureau of Investigation (FBI) search a latent print in their AFIS, known as iAFIS at that time.[29] As a result of that search, the latent print was identified to Brandon Mayfield, an attorney living in Portland, Oregon.[29] On May 19, the Spanish National Police announced that the latent print had in fact been identified to an Algerian Terrorist, Daoud Ouhnane.[29] Figure 17.6 shows the fingerprints of Brandon Mayfield and Daoud Ouhnane alongside the latent print from the plastic bag.

The FBI's erroneous identification, resulting in the 2-week imprisonment of an innocent man, triggered worldwide skepticism regarding the validity of fingerprint comparisons. There were several contributing factors to this case of error. As mentioned in Chapter 7,

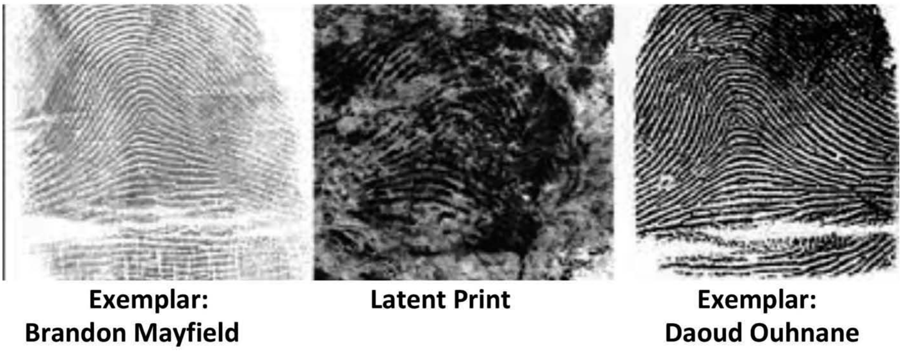


Figure 17.6 The fingerprint on the left is the exemplar print from Brandon Mayfield. The fingerprint in the center is the latent print processed with cyanoacrylate fuming on a plastic bag containing detonators from the Madrid bombing in 2004. The fingerprint on the right is the exemplar print from Daoud Ouhnane.

AFIS searches can result in close non-matches that may bias the examiner toward an unwarranted identification conclusion. Confirmation bias may also have caused the verifiers to identify the latent print erroneously. Other factors contributing to inherent bias include overconfidence on the part of the latent print examiners, all of whom were accomplished and experienced, and the social pressures to identify the individuals responsible for such a heinous attack. The FBI's investigation into the error resulted in the following recommendations: thorough documentation of the ACE-V process; blind verification; quality control for all complex latent print examinations; new quality assurance procedures for high-profile casework; comprehensive proficiency testing; and visual acuity testing. In recent years, these recommendations have become best practice for all latent print examiners.

Routine probability models for fingerprint examinations did not exist in 2004. The identification conclusion in this case could not be quantified to communicate the strength of the evidence. It was simply reported as an identification. Had a probability model been incorporated in this examination, would the erroneous identification have been reported as such? A borderline, complex print such as the one in this case would have merited a lower confidence score than a clear, easy latent print. The incorporation of ACE-V documentation and quantitative statistical models into the fingerprint sciences not only provides transparency in the process, but may also prevent reporting a questionable conclusion in absolute terms in the future.

17.6 Chapter Summary

There is a need for standardization of ACE-V methodology, proper nomenclature for report writing, and the articulation of results in the evaluation phase. Point standards, although still employed in many countries worldwide, are not supported by scientific data. Instead, a qualitative/quantitative approach to fingerprint examination is recommended. Studies have concluded that fingerprint examination has an erroneous identification error rate of between 0.1% and 3% and an erroneous exclusion rate of 7.5%. Probability models give fingerprint examiners the ability to quantify the strength of their conclusions, although few are used routinely in casework today.

17.7 Review Questions

1. Is there a minimum point standard for an identification conclusion? Why, or why not?
2. What are the qualitative and quantitative characteristics that contribute to making an identification conclusion?
3. What is the sufficiency graph?
4. What is a "black box" study?
5. What error rate did the Miami-Dade study determine with regard to erroneous identifications?
6. What were the conclusions of the black box studies conducted by Ulery et al.?
7. What was the erroneous exclusion error rate determined by both the Miami-Dade study and the black box study?
8. What is a probability model in the mathematical field of statistics?
9. Why would a probability model be beneficial for fingerprint examinations?
10. What were some of the issues that contributed to the Madrid error discussed in Section 17.6?

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Palm Print Comparisons

18

> Once examiners are trained to understand the common physical features of the palmar surface of the hand, they soon discover that the palm is not just a large surface area of friction ridge information. Actually, it is a large number of small friction ridge areas joined together.
>
> **Ron Smith**[1]

LEARNING OBJECTIVES

- Name the three major areas of the palm.
- Name the three major creases of the palm.
- Describe the ridge flow in the palm and finger joints.
- Describe the minor creases found in each area of the palm.
- Understand how to orient a latent palm print in order to search exemplars efficiently.

18.1 Palm Print Comparisons

The methodology for comparing latent palm prints with exemplar palm prints is the same as for fingerprints. A fingerprint examiner places the latent print beside the exemplar palm print, either on the computer screen or under a magnifier. The examiner employs analysis, comparison, evaluation, and verification (ACE-V) methodology to analyze, compare, and evaluate the palm print. A second examiner verifies the conclusion. The documentation throughout ACE-V is the same as well.

Fingerprints and palm prints both contain friction ridge detail. Fingerprints and palm prints both contain the same types of minutiae: ending ridges, bifurcations, and dots. Both may contain creases, scars, and other identifying marks. Both can be found at a crime scene or on an item of evidence and can be used for identification or exclusionary purposes. Nevertheless, many fingerprint examiners struggle with palm print comparisons. The reason is because it is often difficult to orient a latent palm print. Which way is "up"? Which part of the palm does the latent represent? Is this ridge detail from the left or right hand? Is it part of a palm, or is it part of a finger?

Compare the surface area of your fingertips to the surface area of your palm. How many fingerprints can fit in one palm print? 15? 20? A latent palm print may be as small as a delta or as large as an entire palm. Smaller sections are more difficult to orient, but are less daunting if you know a few tips and tricks. This chapter addresses some of the common features of the average palm print.

18.2 Anatomical Areas and Major Creases

Palm prints, like fingerprints, can be identified to a common source. It can be difficult to know where to start when confronted with a partial latent palm print. There are many patterns to look for that are common to most palms in the general population and which can narrow down the origin and orientation of the palm fragment. For example, there are four deltas in the palmar area just below the fingers. These deltas each have a distinct position, shape, and associated ridge flow. The patterns and major features discussed in the following sections are common in both hands of most people.

A study of palm prints begins with the general anatomical regions of the palm. The palm and finger joints contain unique areas of ridge flow separated by *creases*. There are three major anatomical areas in the palm: the interdigital, the hypothenar, and the thenar. The *interdigital* area is the portion of the palm directly below the index, middle, ring, and little fingers of the hand (Figure 18.1). The *thenar* area is the portion of the palm at the base of the thumb (Figure 18.2). The *hypothenar*, also known as the "writer's palm," is the portion of the palm below the interdigital area and across from the thenar area (Figure 18.3).

Each anatomical area is associated with one of the three major creases in the palm: the distal transverse crease, the proximal transverse crease, and the radial longitudinal crease (Figure 18.4). Creases are white because they are furrowed areas of skin that do not come into close contact with a substrate and are therefore not developed by powders, ink, or chemicals. Some creases, such as the major creases listed above are wide. Other minor creases are thin and appear similar to white scratches on the surface of a latent palm print.

The major creases of the palm are recorded as curved or jagged white lines in palm latents and exemplars. There are many minor creases throughout the palm that appear in the latent and exemplar prints as straight, jagged, or curved white lines (Figure 18.5). The creases of the hand conform to the flexibility of the hand. The hand bends and flexes along these creases, just as the creases between the finger joints flex as the fingers are bent.

The *distal transverse crease* separates the interdigital area from the hypothenar. The word *distal* refers to anatomical parts of the body located away from the center of the body.

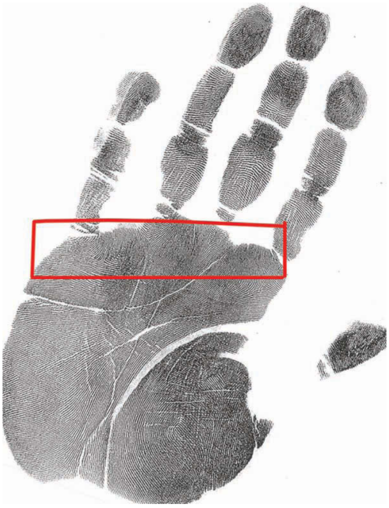


Figure 18.1 The area bounded by the red rectangle is the interdigital area of the palm.

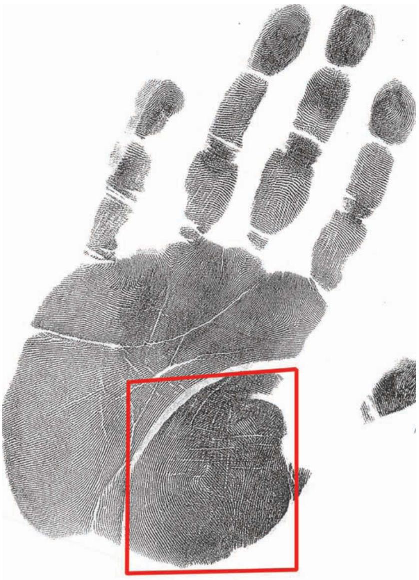


Figure 18.2 The area bounded by the red rectangle is the thenar area of the palm.

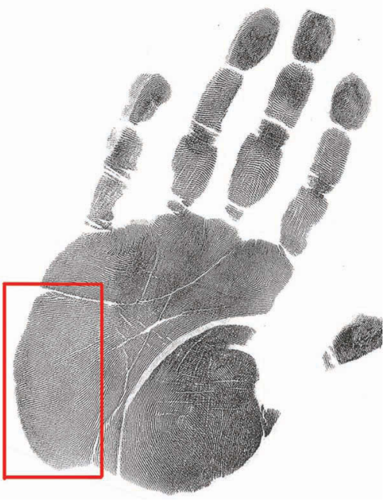


Figure 18.3 The area bounded by the red rectangle is the hypothenar area of the palm.

This crease starts at the edge of the palm hypothenar and ends in the interdigital between the index and middle fingers. At the edge of the hand, the crease is wider and displays a "crow's-feet" pattern (Figure 18.6).[1] The crease narrows and branches where it ends in the interdigital area.

The *proximal transverse crease* separates the interdigital area from the thenar. It runs roughly parallel to the distal transverse crease. Proximal refers to anatomical parts of the body located closer to the center of the body. Therefore, the distal transverse crease is closer to the fingers (and thus farther from the center of the body) than the proximal transverse

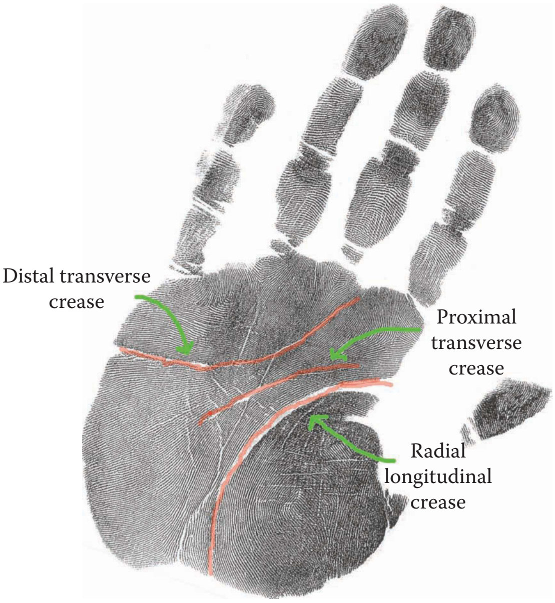


Figure 18.4 The three creases of the palm are the distal transverse crease, the proximal transverse crease, and the radial longitudinal crease.

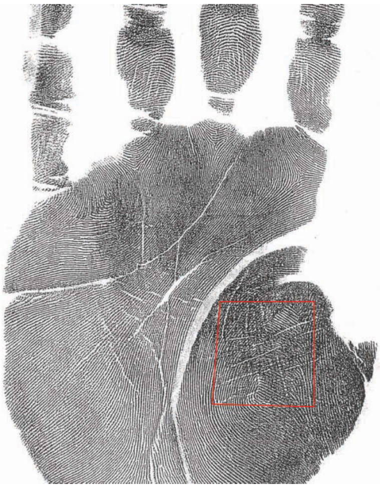


Figure 18.5 The minor creases of the palm are located throughout the palm and finger joints. The area bounded by the red rectangle shows an abundance of minor creases in the thenar area of the palm.

crease. This crease starts at the edge of the webbing of the palm between the thumb and index finger. It ends somewhere in the hypothenar.

The *radial longitudinal crease*, colloquially referred to as the "lifeline," curves along the border of the thenar area of the palm, forming a semicircle. This crease allows the opposable thumb to flex and bend across the palm. The crease begins at or near the proximal

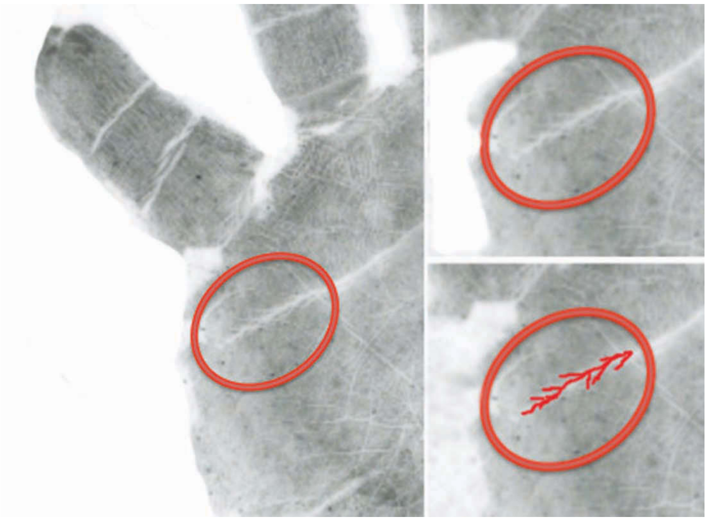


Figure 18.6 When the distal transverse crease exits the palm between the hypothenar and interdigital areas it often displays a crow's feet pattern feathering out toward the edge of the palm.

transverse crease and curves around the thenar to the base of the hand. The length of each crease varies between individuals, just as ridge flow or fingerprint patterns vary.

The fingers above the interdigital area of the palm are separated into *finger joints*. The thumb is made up of two joints, while the fingers are made up of three joints each. Fingerprints are prints from the first (top) joints of the fingers. The second and third joints do not display patterns such as arches, loops, and whorls. However, they all have similar ridge flow.

The creases between the joints are similar between fingers. There is generally one crease between the first and second joints of the fingers. Two creases separate the second and third joints. The index and little fingers have one crease between the third joint and the interdigital area of the palm. The middle and ring fingers are separated from the interdigital area by two creases (Figure 18.7). Although most people have these major anatomical regions in common, the interdigital, hypothenar, and thenar positions, creases and minutiae are unique to each individual.

18.3 Interdigital Area

Fingerprints have a pattern type: a specific ridge flow that is dependent on the proliferation of ridges across the surface of the regressing volar pad during embryological development, as discussed in Chapter 3. The center of the friction ridge area becomes the core of the pattern. Wherever the ridge flow diverges, a delta is formed. There are a finite number of fingerprint patterns (arches, loops, or whorls) that can develop on the surface of the finger. Similarly, the ridge flow on the palmar surface of the hand develops as the volar pads on the palms recede. While it is possible to observe patterns such as loops or whorls in the hypothenar area of the palm, most of the observed ridge flow is unique to the various areas of the palm (Figure 18.8).

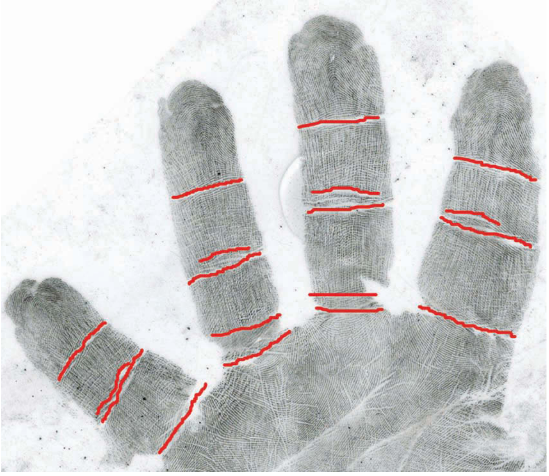


Figure 18.7 There are creases that form between the finger joints. One crease is found between the first and second joints, two creases between the second and third joints, one crease between the third joint and the interdigital of the index and little fingers, and two creases between the third joint and interdigital of the index and little fingers.

The interdigital area has a significant amount of unique ridge detail and patterns in a small area. There are deltas and loops in configurations that may help orient a latent fingerprint. Deltas are located below the index, middle, ring, and little fingers (Figure 18.9). The delta beneath the index finger is more or less shaped like an equilateral triangle. The three angles of the delta are roughly 120° each. The deltas directly under the middle and ring fingers have two obtuse angles and one acute angle forming a "Y" shape. The acute angle points upward. The delta under the little finger is not directly below the finger, but is instead shifted toward the ring finger. The shape is similar to the deltas below the middle and ring fingers, but unlike those deltas, the acute angle faces the delta below the ring finger, like the letter "Y" turned on its side.

The ridge flow in the interdigital area stems from the flow of ridges from these deltas. The ridges originating from the delta under the little finger flow in a loop from that delta

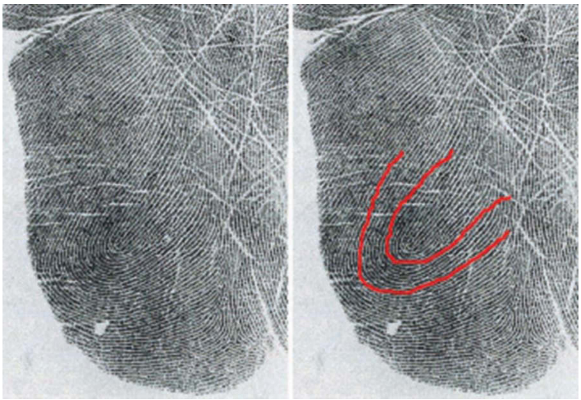


Figure 18.8 A loop pattern in the hypothenar area. (Adapted from an original image by Ron Smith.[1])

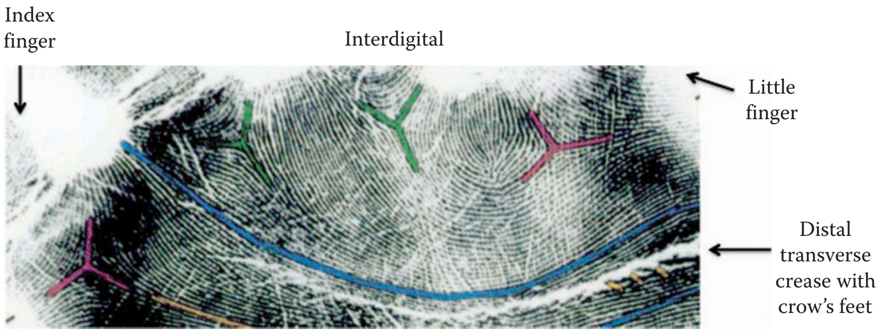


Figure 18.9 The deltas of the interdigital area of the palm (right hand) are indicated in green and purple. The delta under the index finger is equilateral and is located directly beneath the finger. The delta under the little finger, shifted slightly toward the ring finger, forms an acute angle facing the delta of the ring finger. The deltas beneath the middle and ring finger form acute angles facing upward, toward the third joints of the fingers. The ridge flow in the interdigital area is denoted in blue.

to the delta under the ring finger. The ridges originating from the delta under the middle finger flow along the top of the distal transverse crease in a wave pattern and out along the hypothenar side of the hand. The ridges originating from the delta under the index finger flow diagonally across the entire width of the palm. These ridges pass between the distal transverse crease and the proximal transverse crease. The interdigital area is the most variable area of the palm, with its complex concentration of deltas, looping patterns, and ridge flow. The large amount of detail also makes the interdigital area the easiest area to orient when faced with a latent print from that area of the palm.

18.4 Hypothenar Area

The hypothenar is a fairly uniform area of ridge flow. Because of this, and the fact that it is a large area of the palm, it can be difficult to orient latent prints from this area. The ridges of the hypothenar flow at a slight downward angle toward the side of the palm. If you imagine the friction ridges as canals, any water poured into them would flow down and out along the side of the hand.

The friction ridges of the hypothenar that are located near the center of the palm tend to funnel inward. The funnel narrows around the proximal transverse crease, and usually contains many ending ridges. The other end of the funnel widens until the ridges flow out along the side of the hand. The ridge flow toward the base of the hypothenar flattens out similar to a slide at a playground. Although the ridge flow is consistent in most individuals, a loop or whorl pattern may be observed in the hypothenar. The loops and whorls are distinguishable from fingerprint patterns due to their larger size. For example, if you encounter a latent print that appears to be a loop or whorl from an abnormally large finger, check the hypothenar areas for loops or whorls.

At the base of the palm, near the center of the hand, is the *carpal delta*. The carpal delta is the area where the ridge flow from the hypothenar meets the ridge flow of the thenar. The position of the carpal delta differs among individuals and may be located either at the base of the hand near the wrist or higher up in the palm. However, it will always be positioned

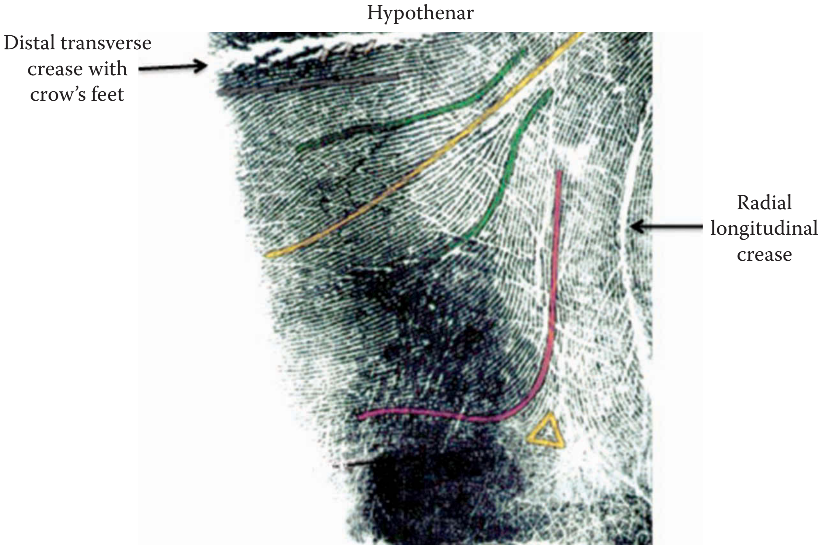

Hypothenar
Distal transverse crease with crow's feet
Radial longitudinal crease

Figure 18.10 The hypothenar area of the palm (left hand). The yellow line denotes the ridge flow from the interdigital delta under the index finger along the proximal transverse crease through the hypothenar. The green curves represent the ridge flow funneling around the proximal transverse crease. The purple curve demonstrates the ridge flow as it flattens out toward the bottom of the hypothenar. The yellow triangle denotes the carpal delta.

near the center of the palm in the junction between the hypothenar and thenar areas. Just below the carpal delta is the wrist, which appears in a latent or exemplar print to be extensively creased but lacking in ridge detail (Figure 18.10).

Minor creases are visible throughout the palm. Most of the minor creases of the hypothenar are located along the edge of the palm commonly known as the writer's palm. These creases are visible as thin white lines that cut across the flow of ridges in that region. This is commonly seen when paper is processed with ninhydrin, as one who is writing tends to rest the writer's palm on the paper substrate.

18.5 Thenar Area

Ridge flow in the thenar is also fairly straightforward in most individuals. This area is bordered on one side by the radial longitudinal crease and on the other by the base of the thumb. The ridges generally flow in a half moon pattern in concentric curves around the thumb. The curves are not uniform, however. The ridge flow nearest the radial longitudinal crease is half moon shaped. Nearer the thumb, the half moon creases become flatter and longer at the top and more curved toward the bottom. While the ridges of the hypothenar flow out the side of the hand, the ridges of the thenar flow out the bottom of the hand (Figure 18.11). It is possible to see a pattern called a *vestige* in the thenar. This unusual pattern looks like two narrow, flattened loops that are positioned head to head. Between the flattened heads of the ridges are friction ridges that are positioned perpendicular to the flow of the surrounding friction ridges (Figure 18.12).

Minor creases in the thenar can help orient latent prints where the ridge flow is unclear. The creases often appear as thin white lines arranged in a basket weave pattern, or appear

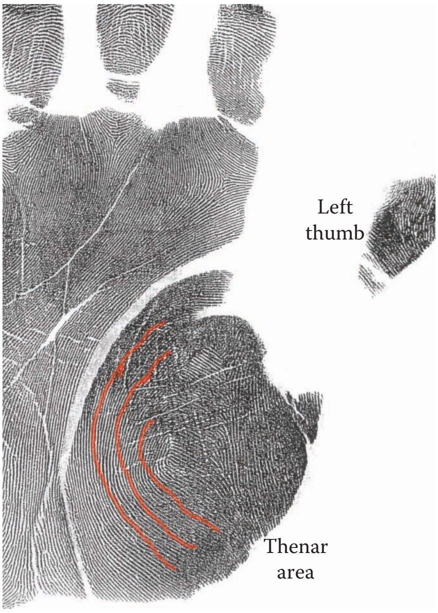


Figure 18.11 The thenar area of the palm (left hand). The red curves denote the half-moon-shaped ridge flow of the thenar.

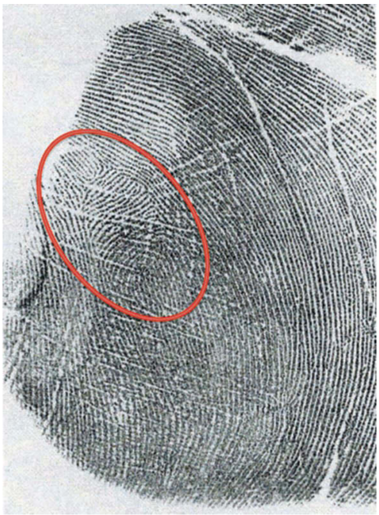


Figure 18.12 A vestige in the thenar area of the palm (right hand). (Adapted from an original image by Ron Smith.[1])

as deeper, horizontal *scratches* (Figure 18.13). Because the webbing between the thumb and index finger is thinner than the muscular base of the thumb, it does not often come into contact with a substrate. A latent palm print may display a large "starburst" crease pattern in that area, which can assist with latent print orientation (Figure 18.14). Also, the edge creases of the thenar are parallel to the flow of the ridges, unlike those in the hypothenar which cut across the flow of the ridges.

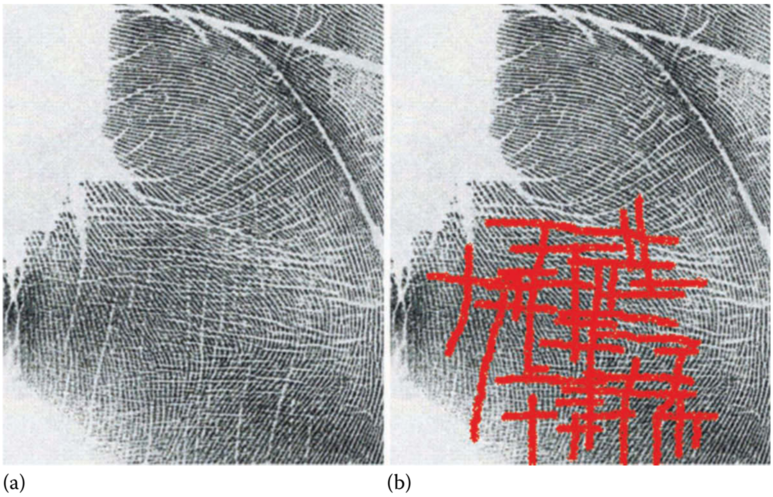

(a) (b)

Figure 18.13 The thenar area of the palm (left) often contains minor creases arranged in a basket weave pattern (right, in red). (Adapted from an original image by Ron Smith.[1])

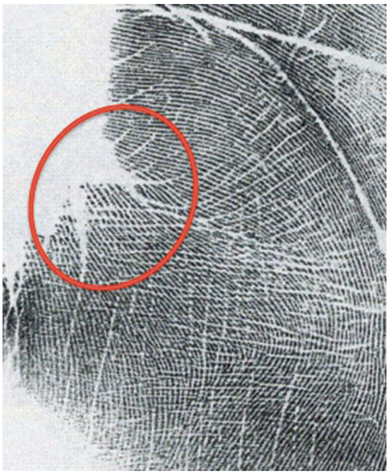


Figure 18.14 The starburst pattern of creases in the thenar. (Adapted from an original image by Ron Smith.[1])

18.6 Finger Joints

The second and third joints do not have arch, loop, and whorl patterns like the first finger joints. The finger joints have many thin vertical minor creases, and it can therefore be difficult to see the pattern of ridge flow. The ridges of the inner finger joints—the ring and middle fingers—are generally horizontal, wavy lines. The outer finger joints—the joints of the little and index fingers—have ridges that slant downward, away from the inner fingers (Figure 18.15). The extensive creases of the finger joints look like vertical scratches in the pattern. These creases are thin and dense. Regardless of the ridge flow and crease pattern

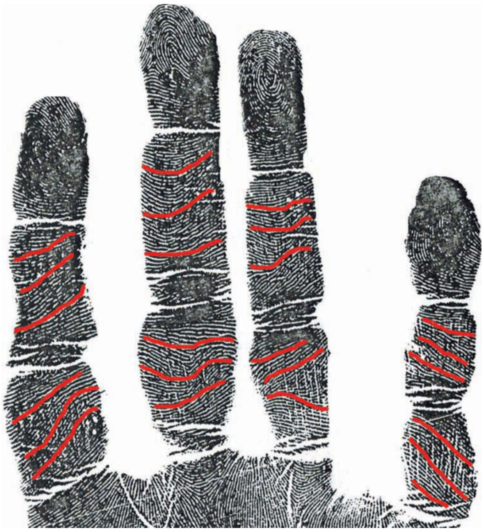


Figure 18.15 General ridge flow in the second and third finger joints. (Adapted from an original image by Ron Smith.[1])

in the latent palm print, an identification can only be affected if the minutiae agree in type and position and no unexplainable discrepancies are present.

18.7 I Had a Case: Finger or Palm?

In 2007, several women in a major city in California were the victims of home invasion and sexual assault. In each instance, the perpetrator gained entry to the woman's home through an unlocked bathroom window. At one crime scene, a latent print was recovered from the exterior window at the point of entry. A garbage can had been pushed up to the window to allow the perpetrator to climb into the home. The latent print, a loop pattern, was searched as a fingerprint in the city's Automated Fingerprint Identification System (AFIS) database without success.

When a suspect was identified several months later, the latent print examiner was not able to identify the latent print to the suspect's exemplar fingerprints. It was then that a second examiner, well versed in palm print anatomy, identified the latent impression as a loop pattern originating from the hypothenar area of the palm and not a finger. The suspect's palm print exemplars were recorded, and he was positively identified as the source of the latent impression. Without the second examiner's knowledge of palm print ridge flow, a critical piece of forensic evidence would have been overlooked and other women might have been victimized.

18.8 Chapter Summary

Palm prints are challenging because it is often difficult to determine the location and orientation of the latent palm prints in order to compare them with exemplar palm prints.

Knowledge of the anatomical parts of the palm makes these comparisons less problematic. The three parts of the hand are the interdigital, hypothenar, and thenar areas. The three major creases of the hand are the distal transverse crease, the proximal transverse crease, and the radial longitudinal crease.

The interdigital area of the hand is the region above the distal transverse crease and below the fingers. There are four deltas in the interdigital area, each associated with one of the four fingers. The ridge flow of this area stems from the deltas. The hypothenar area is characterized by uniform ridge flow that originates from a funnel in the center of the hand and spreads out to exit the side of the hand known as the writer's palm. The thenar area is characterized by half-moon-shaped ridge flow that curves around the thumb. Basket weave patterned creases crisscross the surface of the thenar. The inner finger joints have horizontal, wavy creases. The outer finger joints—the joints of the little and index fingers—have ridges that slant downward, away from the inner fingers.

18.9 Review Questions

1. What methodology is used to compare latent palm prints with exemplar palm prints?
2. What is the area of the palm at the base of the thumb called?
3. What is the area of the palm directly beneath the fingers called?
4. Describe the position and shape of the interdigital deltas and the ridge flow from those deltas.
5. What is the name of the crease that separates the thenar from the hypothenar area?
6. True or false. The second and third joints of the index and little finger have horizontal, wavy ridge flow.
7. Describe the flow of ridges in the hypothenar region of the palm.
8. Where is the basket weave pattern of creases observed?
9. Where in the palm are you likely to see patterns such as whorls or loops?
10. What is the name of the delta positioned near the wrist in the base of the palm?

Reference

1. Smith, R. 2006. Advanced palm print comparison techniques. Workshop Presented by Ron Smith and Associates, Inc. Sponsored by the International Association for Identification and the California Department of Justice Automated Latent Print Section. Rancho Cordova, CA.

Courtroom Testimony

19

The right to search for truth implies also a duty; one must not conceal any part of what one has recognized to be true.

Albert Einstein

LEARNING OBJECTIVES

- Understand the role of the expert witness in the judicial system.
- Give examples of how to be an effective teacher on the witness stand.
- Explain the three main phases of expert testimony and how the fingerprint analyst prepares for each phase.
- Describe the importance of a pretrial conference.
- Describe the demeanor and dress of the successful expert witness.
- Explain the Daubert trilogy and how it applies to fingerprint testimony.

19.1 The Expert Witness

Regardless of the type of fingerprint examination conducted, all fingerprint examiners will, at some point in their careers, testify to their actions and conclusions in a court of law. As a forensic scientist, the fingerprint examiner must not only conduct scientific analyses but also communicate conclusions to the layperson. Although the forensic scientist may be more comfortable working at a desk, in a laboratory, or at a crime scene, the final stop for some criminal investigations is, inevitably, the courtroom.

Many criminal cases never make it to court. The accused either takes a plea deal (admits guilt and accedes to a predetermined punishment) or is never brought to trial. Regardless of how often a fingerprint examiner testifies, it is critical that all forensic scientists receive training to prepare for testimony. The fingerprint analyst should practice testifying by participating in *moot court* sessions. Moot courts are mock trials that allow fingerprint examiners to practice their testimony so they know what to expect and are prepared for an actual trial.

A forensic scientist who testifies in court is considered an *expert witness*. An expert witness is anyone who knows more about a particular topic than the average person. This is defined by the Federal Rules of Evidence (FRE), which governs how evidence is presented in a court of law. *Federal Rule of Evidence* 702 (FRE 702), adopted in 1975, applies to scientific and technical experts, as follows:

> If scientific, technical, or other specialized knowledge will assist the (judge and/or jury) to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training or education, may testify thereto in the form of an

> opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.[1]

It is up to the judge to determine whether the science to be presented in a court of law meets the above criteria.

The difference between a lay witness and an expert witness is that an expert witness can testify to his or her opinion. A lay witness must only testify to what was seen, experienced, or heard. The following is an example of the difference between the lay witness testimony and the expert witness testimony.

- Lay witness: *I saw him running away from the house. He was wearing a black baseball cap and a red sweatshirt.*
- Fingerprint examiner: *It is my opinion that the latent print found inside the point of entry originated from the same source as the suspect's right thumb print from the inked exemplar.*

The following is an example of lay witness testimony versus the testimony of a trace evidence examiner testifying to characteristics of hair:

- Lay witness: *She had long brown hair.*
- Trace evidence examiner: *The hair analyzed is human in origin, dark brown, and artificially treated. It shows characteristics of Asian descent. It is 36 cm long.*

Forensic scientists benefit from some degree of flexibility in this regard, as they are often able to teach the jurors about their science at length.

19.2 The Judicial System

In many judicial systems, the main players in the courtroom are the prosecutor, defendant, judge, and jury. The justice system is an adversarial system, meaning there are two sides presenting their case to the trier of fact (judge or jury). One side is called the *prosecution* and is the side representing the state, federal government, or complainant. The other side is the *defense*. The defendant is the individual accused in a civil or criminal action. Each side presents its case to the jury by questioning witnesses and presenting evidence. The job of the attorney is to present a narrative, or theory, of the case. A narrative is, in a sense, a story about what may have happened.

The judge is the referee in a courtroom (Figure 19.1). The judge makes sure both sides follow the rules and settles disputes. Judges have many other functions, but in a criminal trial, the expert witness should be aware of the judge's role as a moderator. Attorneys may object to portions of the expert's testimony or to the question asked by the opposing side. When this happens, the witness must stop talking and wait for the judge to rule on the objection. He may *sustain* the objection, verifying that the objection has merit. Or he may *overrule* the objection, declaring it invalid. Either way, proceedings will continue after the judge's ruling. The judge decides questions of the law and keeps order in the courtroom.

Figure 19.1 A judge directing proceedings in a courtroom in the United States.

Prior to a jury trial, each potential juror is asked a series of questions during the process of *voir dire*. The purpose of voir dire is to determine which individuals are best suited to serve on the jury for the case at hand. The individuals chosen to serve on the jury have the obligation to view all the evidence presented and listen to both the attorneys' narratives of the case and the witnesses brought forth. Following the trial, the jury is responsible for determining guilt or innocence.

19.3 Testimony Is Teaching

Juries are made up of laypersons from a variety of backgrounds and occupations. A jury may consist of a grandmother, a nuclear physicist, a college student, a stay-at-home mom, a doctor, and others. Because the average jury is made up of a diversity of individuals of various socioeconomic and educational backgrounds, it can be challenging to explain scientific examinations in a way that is understood by all. The successful fingerprint expert can successfully explain the science behind the analysis to the average person.

We have all had teachers who have made an impact in our lives. What qualities did those teachers possess? What makes them great teachers? The following is a list of the qualities of an effective teacher:

- Knowledgeable about the topic at hand
- Relatable
- Enthusiastic
- Uses visual aids
- Uses anecdotes and examples
- Defines terms in plain language

If a fingerprint analyst displays excellent teaching skills, he or she will be a successful, sought-after expert witness and a successful forensic scientist. Similarly, those who have experience with public speaking make great expert witnesses because they display the following qualities of an effective public speaker:

- Speaks with appropriate volume
- Makes eye contact
- Acts naturally
- Does not fidget or display nervous gestures
- Exudes confidence and competence
- Demonstrates passion about the topic presented

How might a fingerprint examiner incorporate these qualities into courtroom testimony? Most people are not born with these qualities. It takes practice to become an effective teacher and public speaker. The fingerprint analyst should plan out courtroom testimony ahead of time and think of ways to incorporate the qualities listed earlier. If while testifying the jury looks disinterested, employ some of the tactics given earlier to maintain their interest. Encourage them to look at their own fingerprints. Show the jury visual aids. Modulating speech conveys passion and interest in the topic. Use anecdotes and examples to relate difficult scientific concepts or processes to their daily lives.

While it is important to understand how to be an effective teacher, it is also helpful to understand how people learn. The following are common learning styles:

- Solitary—learns best by analyzing information independently
- Social—learns best by analyzing information in a group setting
- Visual—learns best with pictures, graphs, and charts
- Aural—learns best by listening and benefits from repetition
- Physical—learns by doing
- Logical—needs information presented in a step-by-step manner
- Verbal—learns by teaching or discussing information with others

Each person, and therefore each member of the jury, learns best in different ways. Some people are visual, social learners while others are logical and solitary. Adapting testimony to each type of learning style will maximize the expert's impact on the jury and ensure that the witness is both understood and holding the jury's attention.

It is challenging to explain scientific concepts to the layperson. This is a skill that must be practiced. If a fingerprint examiner routinely uses cyanoacrylate fuming in casework, that examiner should expect to have to explain cyanoacrylate fuming in court. It is helpful to write out a basic description of each process and practice explaining it to the layperson prior to testifying in court. The following is an example of a fingerprint examiner's expert witness testimony:

What is a latent print?

If you look at your fingers and palms, you might be able to see minute lines on the surface of the skin. These lines are known as friction ridges. Quite literally, the bumpy surface provides friction between your hand and anything you might handle, such as a water bottle [examiner lifts the water bottle on the witness stand]. The friction ridges help you grip the bottle to keep from dropping it.

When you touch an object, sweat and other substances (such as lotion, grease, or cosmetics) coating the friction ridges transfer the pattern to that surface. For example, when I touch this wood surface (expert touches the witness stand), the sweat and lotion coating my friction ridges are deposited onto the wood surface. This is similar to a rubber stamp, which deposits ink onto a piece of paper in the exact pattern of the stamp. Unlike a rubber stamp, which has visible ink, our fingerprints are invisible. An invisible fingerprint is called a latent fingerprint. Latent is Latin for "hidden." We then have to make those invisible fingerprints visible using fingerprint powders or special chemicals.

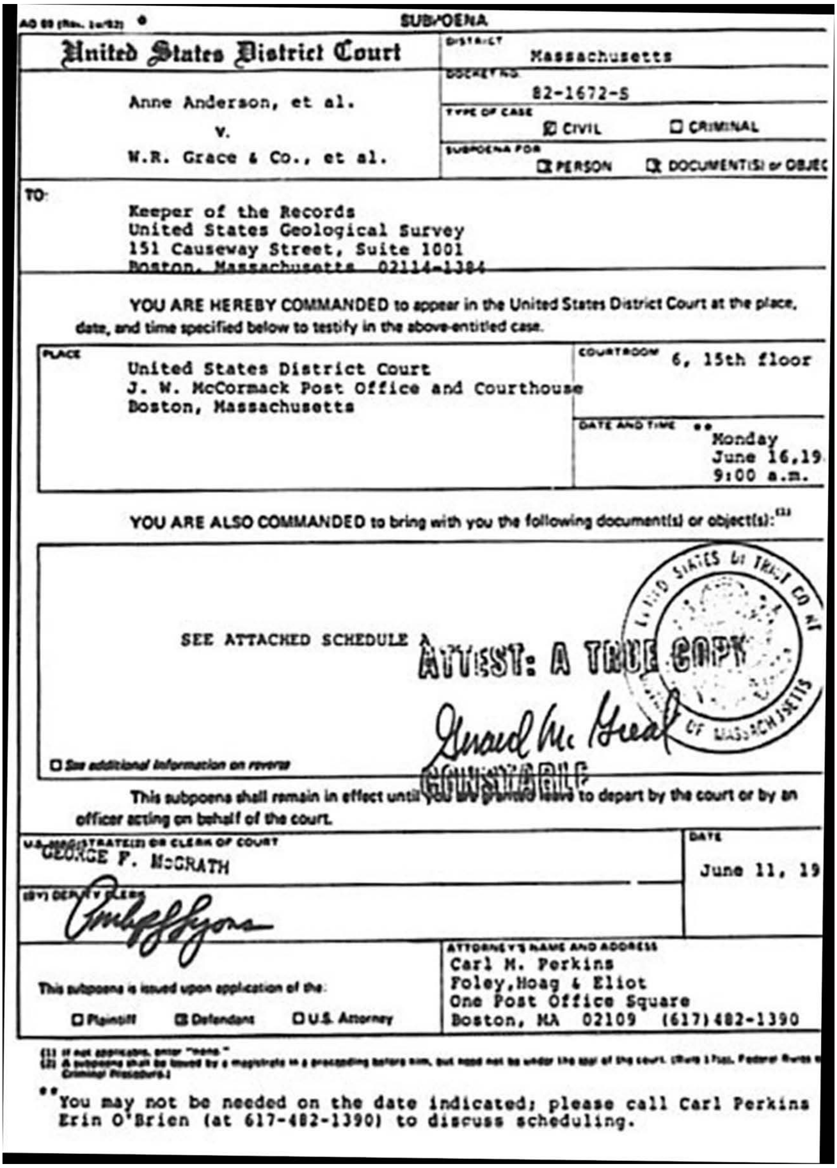
This testimony reflects the aforementioned teaching tools. The visual learner and the physical learner will benefit from the expert asking them to look at their own hands, along with the physical demonstration of touching the witness stand in order to demonstrate latent print deposition. This description also benefits from the use of analogy – the rubber stamp being analogous to the pattern of friction ridges on the finger. These teaching tools can be used during any phase of testimony, but are usually employed during the jury education phase of qualifying questioning or direct examination.

19.4 Preparing for Court

Prior to the trial, the expert witness receives a *subpoena*. A subpoena is an order to appear to testify as a witness on a particular date and time (Figure 19.2). Once the subpoena is received, the fingerprint examiner should call the attorney's office to schedule a pretrial conference. A *pretrial conference* is a meeting with the attorney prior to the start of the trial during which the forensic expert explains his or her qualifications, analyses, results, conclusions, and any other information relevant to the case. It affords the expert the ability to explain his or her results and why they are relevant to the case at hand. The expert witness can also address any problems with the analysis, challenges, or issues that may arise during cross-examination.[2] This is also the time when it is appropriate to provide the attorney with an updated curriculum vitae (CV) and any visual aids that may be used during testimony (Section 19.6). All materials are discoverable by the defense, so they must be given the opportunity to evaluate these materials prior to trial.[3]

The attorney is an expert in the law, not in fingerprint analysis. It is therefore important to educate the attorney. Attorneys juggle multiple cases at one time and may not initially want to schedule a meeting. Insist on a pretrial conference. This will ensure that there are no surprises or confusion at the trial. Both the expert witness and the attorney will be better prepared.

When preparing for both the pretrial conference and the trial itself, gather and review all relevant case documentation. This documentation may include photographs, diagrams, bench notes, laboratory worksheets, AFIS print outs, final reports, and anything else relevant to the examiner's involvement with the case. Is the documentation accurate and complete? If there is an error, now is the time to correct that error and provide a corrected copy of the document to the attorney. The expert witness's CV should be professional, current, and complete so that a copy can be provided to the attorney (see Appendix D). Organize all documents so they can be easily referenced on the witness stand, if the expert's jurisdiction allows him or her to utilize these materials on the stand. If not, memorize the relevant information and practice the testimony out loud.



AO 89 (Rev. 1/82) •

SUBPOENA

United States District Court

DISTRICT
Massachusetts

DOCKET NO.
82-1672-S

Anne Anderson, et al.
v.
W.R. Grace & Co., et al.

TYPE OF CASE
☒ CIVIL ☐ CRIMINAL

SUBPOENA FOR
☒ PERSON ☒ DOCUMENT(S) or OBJEC

TO:
Keeper of the Records
United States Geological Survey
151 Causeway Street, Suite 1001
Boston, Massachusetts 02114-1384

YOU ARE HEREBY COMMANDED to appear in the United States District Court at the place, date, and time specified below to testify in the above-entitled case.

PLACE
United States District Court
J. W. McCormack Post Office and Courthouse
Boston, Massachusetts

COURTROOM
6, 15th floor

DATE AND TIME **
Monday
June 16,19
9:00 a.m.

YOU ARE ALSO COMMANDED to bring with you the following document(s) or object(s):(1)

SEE ATTACHED SCHEDULE A

ATTEST: A TRUE COPY

CONSTABLE

☐ See additional information on reverse

This subpoena shall remain in effect until you are granted leave to depart by the court or by an officer acting on behalf of the court.

U.S. MAGISTRATE(2) OR CLERK OF COURT
GEORGE F. McGRATH

DATE
June 11, 19

(BY) DEPUTY CLERK

This subpoena is issued upon application of the:
☐ Plaintiff ☒ Defendant ☐ U.S. Attorney

ATTORNEY'S NAME AND ADDRESS
Carl M. Perkins
Foley,Hoag & Eliot
One Post Office Square
Boston, MA 02109 (617)482-1390

(1) If not applicable, enter "none."
(2) A subpoena shall be issued by a magistrate in a proceeding before him, but need not be under the seal of the court. (Rule 17(a), Federal Rules of Criminal Procedure.)

**You may not be needed on the date indicated; please call Carl Perkins
Erin O'Brien (at 617-482-1390) to discuss scheduling.

Figure 19.2 A copy of subpoena from a United States federal court case. (Reprinted from the Science Education Resource Center (SERC), an office of Carleton College. Retrieved December 10, 2013, from http://serc.carleton.edu/files/woburn/resources/subpoena_usgs.jpg.)

When the documentation is in order, the examiner can prepare visual aids. The examiner may choose to prepare a short slideshow or presentation to assist with jury education. Some fingerprint analysts prefer to draw as they teach. For example, one can draw a simple diagram of a bifurcation, dot, and ending ridge, fingerprint pattern types, or the layers of the skin. If fingerprint comparisons were done, a clear, enlarged court chart is desirable so the jury can follow along as the process is described (Figure 19.3).

It is natural to be nervous on the day of trial; however, there are things the examiner can do to minimize nervousness and maximize preparedness. Familiarizing oneself with

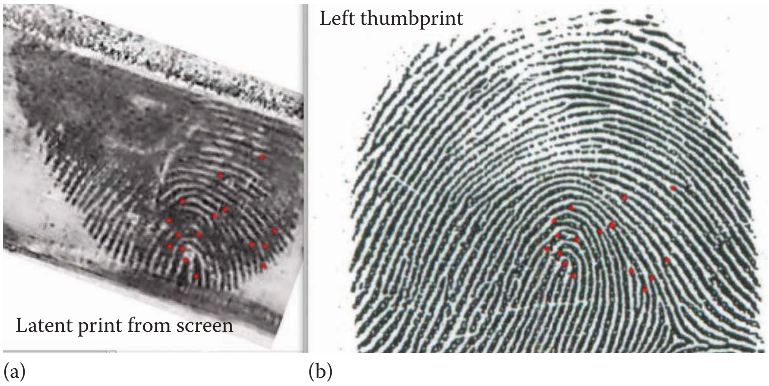


Figure 19.3 A court chart illustrates the comparison of a latent print (left) to a known print (right).

the case, gathering the documentation, and preparing teaching aids will alleviate some of the tension and nervousness. Another way to minimize nervousness is to visit the courtroom (Figure 19.4). Familiarization with the location of the courthouse and courtroom, where to park, the layout of the courtroom, the location of the witness waiting area, and the path to the witness stand can take away unknown variables that contribute to feelings of apprehension. Is there a witness waiting room outside the courtroom? Do the doors swing outward or inward? Is the witness stand behind a podium? (Figure 19.5). Is there a microphone? The examiner may be able to attend a case in progress. If visual aids requiring audiovisual equipment will be used, where are the hookups and plugs? Where should the expert stand so as not to impede the jury's view? It may even be possible to test out the equipment ahead of time. Knowing the environment will take away many unknown factors that lead to nervousness.

The expert must dress professionally for court. For men, this means a suit and tie. For women, a pants suit or knee-length skirted suit is acceptable. Clean, polished, conservative shoes are best. For women, heels should be low and neutral in color. In his book *Dress*

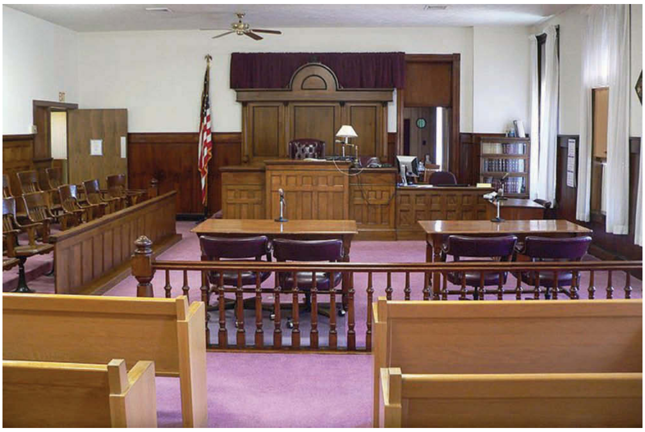


Figure 19.4 The layout of a typical courtroom in the United States.

Figure 19.5 Witness stand in a typical courtroom in the United States.

for Success, John Molloy explores the impact of appearance on the perceptions of others. Molloy notes that jurors respond more positively to professionals dressed in a conservative blue or gray business suit who carry a light briefcase.[4] The expert should wear nothing to distract the jury such as a colorful tie, large jewelry, or heavy makeup. Jingling keys or coins also distract jurors.

Looking like an expert does not stop at appearance. It is also in the expert's *demeanor*. Demeanor refers to how one carries oneself: the way the expert stands, moves, and conducts himself or herself. Even if the expert is nervous, he or she must stand up straight and exude an air of self-confidence. Jurors do not respect or respond to experts who act nervous, slouch, or fidget. Experts who appear timid or uncertain also open themselves up to aggressive cross-examination. Articulate, confident experts will hold the jury's attention. Remember that public speaking is:

10% what you say
20% how you say it
70% how you look

The following are criteria for the ideal expert witness, according to attorney and forensic science consultant Gil Sapir: "knowledge, reputation for honesty, objectivity, personal appearance, dignity, voice, modesty, even temperament, memory for facts without references, communication skills, integrity, trustworthy, and ability to teach and educate."[5]

In *Advances in Fingerprint Technology*, Hazen and Phillips offer the following suggestions for becoming a successful expert witness:[6]

1. Conduct mock court sessions and obtain feedback.
2. Test answers to the basic qualifying questions on lay persons and obtain feedback.
3. Dress the part.
4. Listen.
5. Think positively.
6. Remember at all times to be objective.
7. Watch the jury for nonverbal communication feedback.
8. Learn to effectively use silence.

Practice, preparation, and professionalism are the keys to successful expert witness testimony.

19.5 The Day of Court

Get a good night's sleep and eat breakfast the day of trial. Bring all documentation. Arrive at the courtroom early. The expert should be dressed professionally and have a professional demeanor from the moment he or she enters the courthouse. Allow some time to check in with the attorney and locate the courtroom. The expert may have to wait in a witness waiting room or hallway. Anyone encountered upon entering the courthouse may have some role in the proceedings. Be polite and professional when addressing people, but never discuss the case at hand with anyone.

The expert is called into the courtroom when it is his or her turn to testify. When the expert enters the courtroom, he or she walks confidently to the witness stand with a professional demeanor and good posture. The officer asks if the expert swears to tell the truth. The proper response is, "I do." The expert takes the oath with a clear voice that can be heard by the entire courtroom. When the expert has taken the oath, the witness is instructed to sit. Take a seat and arrange the appropriate documentation on the podium, if applicable.

The first questions asked during the testimony of an expert are usually qualifying questions, followed by direct examination and cross-examination. During each phase of testimony, the expert witness makes eye contact with the attorney asking the question and directs the answer to the jury. A successful expert witness makes eye contact with each juror during the course of his or her testimony, since the jurors are the audience.

19.6 Qualifying Questions

During the first phase of testimony, an attorney may ask the expert *qualifying questions*. The attorney asks the forensic scientist questions to determine whether he or she is qualified to testify as an expert in a court of law. These qualifying questions can be prepared ahead of time and provided to the attorney at the pretrial conference. Qualifying questions for a fingerprint expert may include questions about the expert's employment, experience, education, professional training, knowledge of fingerprint science, and professional affiliations. All this information, other than fingerprint history and scientific concepts, should be included in a CV: a professional resume. See Appendix D for more information about writing a CV.

During qualifying questioning, the expert witness may also be asked about the number of crime scenes examined, the total number of fingerprint comparisons conducted, the number of times the expert has testified in a court of law, the number of presentations given, or how many articles have been published. Experts generally testify to the former by estimating the number of crime scenes examined and the number of fingerprint examinations conducted. For example, the average fingerprint examiner compares thousands of fingerprints before being entrusted with casework. If a fingerprint examiner compares an average of 20 fingerprints per day, work 5 days per week and 50 weeks out of the year, he or she conducts approximately 5,000 fingerprint comparisons per year.

The expert may also be asked whether he or she is a member of a professional organization or association such as the International Association for Identification (Figure 19.6),

Figure 19.6 The logo of the International Association for Identification. (Reprinted with permission from the International Association for Identification.)

has ever held a position of leadership in that organization, or is certified in his or her field of expertise. To enhance one's professional credibility, it is important to stay abreast of scientific developments in the field and take an active interest in one's profession. Membership in a professional association can help achieve this by giving the forensic scientist access to scientific journals, professional connections, opportunities to present at conferences, and opportunities to become involved with committees and special projects.

Regardless of duration of experience, the forensic scientist is qualified to testify as an expert witness because of the knowledge, skills, and abilities received above and beyond those of the layperson. It is unethical, and unlawful, to embellish accomplishments on a CV or during the qualifying phase of testimony. If the expert witness exaggerates or blatantly lies about his or her level of experience or background on the witness stand, it is considered *perjury*. Perjury is the act of falsifying information while under oath and is a criminal act.

The best way to prepare for the qualifying phase of testimony is to prepare one's own qualifying questions for the attorney. The forensic scientist is the expert; he or she knows which questions are relevant and which questions highlight his or her expertise to the judge and jury. If the expert witness is aware of the questions ahead of time, he or she can prepare answers to those questions prior to testifying in court. This not only gives the expert the opportunity to practice but also provides the confidence to know there will be few, if any, surprises during testimony. Those questions and answers must be made available to the opposing attorney. Be prepared for questions about this during cross-examination.

The following is a sample list of qualifying questions (and answers) for a fingerprint expert:

Please state and spell your name.

My name is John Smith. J-O-H-N S-M-I-T-H

What is your official job title?

I am a fingerprint examiner.

By whom are you currently employed?

I am currently employed by the Anywhere Police Department.

What are your duties as a fingerprint examiner?

As a fingerprint examiner, I examine latent prints from items of evidence associated with various crimes as well as from crime scenes. I perform laboratory examinations using fingerprint powders and chemicals to develop latent prints on evidentiary items. I then compare those latent prints with known prints and form an opinion about the source of the latent prints.

How long have you been employed as a fingerprint examiner?

I have been employed as a fingerprint examiner for approximately 2 years.

How many fingerprint examinations have you done during your career?

I have examined over a hundred cases, resulting in thousands of fingerprint comparisons.

What is your educational background?

I have a Bachelors of Science degree in biology and a Masters of Science degree in forensic science, both from the University of Anywhere.

Have you received any other training in fingerprint analysis?

Yes. I have attended two professional training conferences. I also attended a 40-hour course entitled “Fingerprint Comparisons” and a 24-hour course entitled “Comparing Palm Prints.”

Do you belong to any professional organizations?

Yes. I belong to the International Association for Identification.

Have you published any articles or books on the subject?

Yes. I published a Master’s thesis in 2011 entitled “Novel approaches to fingerprint development on unfinished wood surfaces”.

Have you testified as an expert in a court of law?

Yes.

How many times?

Three times.

You mentioned you examine latent fingerprints. What is a latent fingerprint?

If you look closely at your fingers, you notice there are patterns made up of ridges, which we call friction ridges. Along each friction ridge are pores. These pores excrete sweat, which coats the friction ridges. When you touch a surface, the pattern of your fingerprint may be transferred to that surface. This is similar to a rubber stamp coated in ink, which deposits its pattern onto a surface. Unlike the ink on a rubber stamp, the pattern formed by the transfer of sweat to a surface is invisible. Latent fingerprints are fingerprints that cannot be seen by the human eye. They require some type of development technique, such as fingerprint powder or chemicals, to make them visible. Latent fingerprints are from an unknown source and must therefore be compared with known fingerprints.

What are known fingerprints?

Known fingerprints, or exemplars, are fingerprint records from a known source. They are intentional reproductions of the friction ridges. For example, when someone is arrested, their fingerprints are taken to verify their identity. A thin layer of ink is applied to the friction ridges and then rolled onto a special card called a tenprint card. The individual's name and identifying information are on that card. Similarly, an individual's known prints can be recorded digitally with a Livescan machine, which scans your fingerprints just like a document scanner scans text.

How do you go about comparing latent fingerprints to known fingerprints?

The friction ridges on your hands and feet are not continuous. A ridge may diverge to form two ridges, similar to a fork in a road. This is called a bifurcation. Another ridge may abruptly stop. This is called an ending ridge. There are also short ridges: some so short they appear to be dots. The places where the ridges diverge or abruptly stop are called minutiae, or points. Each fingerprint contains a unique assortment of these minutiae throughout the pattern. Fingerprint examiners compare the placement and types of minutiae in the latent fingerprint with the placement and types of minutiae in the known fingerprint. If the same minutiae are present in both prints in the same configuration, I can determine as a result of my training and experience that those two fingerprints likely come from the same source.

Why is it that fingerprints can be used as a means of identification?

Fingerprint identification is based on two premises; one, that fingerprints are unique; and two, that fingerprints are persistent. Fingerprints develop before birth in a randomized, natural process that is dependent on both genetic and environmental factors. This makes them unique.

Fingerprints are also persistent, which means they will not change over time unless due to injury or disease. The fingerprints you are born with are the fingerprints you have as an adult. Fingerprints are formed in a deep layer of skin called the basal layer, which forms the blueprint for the arrangement of friction ridges and minutiae you see on the surface of the skin. That blueprint is changed only if the basal layer is damaged. For example, if you cut your finger deep enough to penetrate the basal layer, it will form a scar. Because fingerprints are unique and persistent, we can use them to identify the source of a latent fingerprint by comparing it with a known fingerprint.

After the qualifications and knowledge of the subject matter have been evaluated, the judge will accept or reject the fingerprint examiner as an expert in the field of fingerprint analysis.

19.7 Direct Examination

The next phase of expert witness testimony is the *direct examination* of the expert witness. During direct examination, the attorney who subpoenaed the expert will ask questions. These questions are related specifically to the examiner's actions and conclusions. During the pretrial conference, the expert discusses the analyses and conclusions and helps the attorney formulate a line of questioning for the direct examination phase of testimony. The questions asked during this phase will be open-ended allowing the expert to elaborate where needed and teach the scientific concepts to the jurors. The following are examples of questions asked during the direct examination phase as a continuation of the earlier examples of questions asked during qualifying questioning:

Do you recognize exhibit #1?

Yes. My initials appear on the evidence seal on the outer packaging.

What is exhibit #1?

Exhibit #1 is one sheet of note paper approximately 3 × 5″ in size

Did you examine exhibit #1 for fingerprints?

Yes.

How did you examine exhibit #1?

I first conducted a visual examination on the paper, and did not see any visible fingerprints. Then I processed the paper for latent prints using a chemical called ninhydrin. This chemical reacts with the amino acids and proteins in sweat and turns latent prints a purple color. After I processed the paper with ninhydrin, I was able to visualize one latent print on the front of the paper. I photographed the resulting latent fingerprint, which I labeled L001.

Did you also perform any fingerprint comparisons in this case?

Yes.

Which fingerprints did you compare?

I compared the unknown latent fingerprint, L001, with the known fingerprints of the suspect, Jim Daniels.

How were these known fingerprints recorded?

The known fingerprints were recorded on a tenprint card in ink.

And how did you perform your comparison?

I compared the minutiae in the latent fingerprint with the minutiae in the known fingerprint using ACE-V methodology.

What is ACE-V methodology?

ACE-V is the methodology fingerprint examiners use to compare unknown latent prints with known prints in a systematic fashion. ACE-V stands for analysis, comparison, evaluation, and verification. During the analysis phase, I look at the overall pattern and quality of the latent print and determine if it is sufficient for comparison purposes. I take notes about the ridge flow, observable features, and any distortion I may observe in the print. I also mark the minutiae I see in the latent print. Then I move on to the comparison step. During the comparison phase, I compare the minutiae of the latent fingerprint to the minutiae in the known fingerprint. Next comes the evaluation step. During the evaluation phase I come to one of three conclusions: identification, exclusion, or insufficient. The identification conclusion means that both the known and the latent print likely come from the same source. The exclusion decision indicates that the known and latent prints come from different sources. The insufficient determination means that no identification or exclusion conclusion could be reached. Finally, we come to the "V" in ACE-V: verification. The verification phase is a peer review process at which time another qualified fingerprint analyst repeats the analysis, comparison, and evaluation phases and comes to his own conclusion about the source of the latent print. This is the methodology I followed in this case. I brought a charted enlargement of the fingerprint comparison to court today as a demonstration.

Is this chart a true and accurate representation of the latent and known fingerprints you used for your comparison?

Yes. This is an enlarged copy of the photograph of the latent print and the known print of the right index finger of the suspect.

Can you please walk us through the comparison process?

[Expert demonstrates the comparison process by pointing out corresponding minutiae between the latent and known fingerprints on the chart.]

What was your conclusion in this case, regarding the latent print you developed on exhibit #1?

Utilizing ACE-V methodology, I concluded that fingerprint L001 is consistent with the right index finger of Jim Daniels.

It is important to stay on track and answer only the questions asked during direct examination. When a question is asked, take a moment to think about the question. Take a deep breath. Formulate an answer. And answer only the question asked. It takes only a few seconds to pause, although it may seem longer on the witness stand. When expert witnesses rush into answering questions, whether out of nervousness or habit, they may end up not answering the question at all, explaining beyond the scope of what was asked, forgetting a crucial detail, or confusing the jury. Taking a minute to pause and think about the answer ensures more accurate and effective expert witness testimony.

As the attorney asks questions, there may be a need to address legal matters. There may be objections to questions asked. The attorney may need to ask the court whether a particular item or document be admitted as evidence. Evidentiary items admitted as evidence in court are known as *exhibits*. Regardless of the interruption, immediately stop speaking and wait for the judge to indicate that it is appropriate to continue. At that time, ask the attorney to repeat the question if necessary.

19.8 Cross-examination

At the conclusion of the direct examination phase of testimony, the opposing attorney has an opportunity to ask questions of the expert witness. This is the *cross-examination* phase. Cross-examination questions are most often *leading questions*: short, declarative statements of fact where the attorney suggests the answer by the nature of the question. These questions can usually only be answered "yes" or "no," although the expert witness has some leeway to elaborate where needed. Defense attorneys use leading questions to control the expert witness and present their narrative—or theory—of the case.

Unlike the qualifying questioning and direct examination, the forensic expert will likely not know what questions will be asked. Certain questions can be anticipated because they logically follow up on the questions asked during direct examination. Also, if there were issues with the case or errors in the report or process, they expect to answer questions addressing these errors during cross-examination. While it is prudent to anticipate possible lines of questioning prior to trial, it is not advised to do so during the cross-examination process. Simply concentrate on the questions asked and answer truthfully.

Consider the following example. A car is burglarized outside an apartment. During the crime scene investigation, a fingerprint is developed on the exterior of the car's trunk. The latent fingerprint is identified to the suspect. What questions may arise that are relevant to the case? The defense attorney may ask, "Isn't it possible that my client, who lives in the adjacent apartment building, could have touched the car while walking by?" Yes, this scenario is possible. Or the attorney may ask, "Just because his fingerprint is on the car, does that mean he is responsible for burglarizing the car?" No, it does not necessarily mean he is responsible for burglarizing the car. As an impartial scientist, the fingerprint examiner does not have a stake in whether the prosecutor "wins" or "loses" at trial. The job of a forensic scientist is to present the facts and answer the questions truthfully and to the best of one's ability. This is how trustworthiness and professional credibility are developed as a forensic scientist.

The defense attorney's role is to ensure that the accused gets a fair trial. In the United States, this is a right guaranteed by the Sixth Amendment to the Constitution. The role of defense attorneys is to ensure that the facts are accurately stated. They ensure that every applicable forensic analysis was completed accurately and thoroughly. They may attempt to find inconsistencies in the expert's testimony. They may try to discern whether the expert is biased or has committed ethical violations. The scientist has nothing to fear from cross-examination. The defense attorney should be treated with the same respect the forensic scientist gives to the prosecuting attorney. Always be polite, make eye contact, and address the attorney respectfully.

The defense attorney is trained to use tactics to challenge the expert witness. The attorney may ask questions at a rapid pace. The simple solution is to pause after every question and answer truthfully, just as during direct examination. Another tactic the attorney may employ is asking compound questions: multiple questions asked at the same time that may require separate answers. This can be mitigated by politely asking the attorney to ask one question at a time. The attorney may use a loud voice, stand between the expert and the jury, or use other tactics to pull attention away from the expert. The expert witness can control the speed and flow of testimony by simply pausing after each question.

Rarely a defense attorney will utilize more aggressive tactics. If the defense attorney becomes aggressive towards the witness, and the witness handles this in a professional manner, the jury will sympathize with the expert witness and turn against the attorney. After all, they would not want to be sitting up there in the expert's place. This is something the attorney does not want to happen, and is generally not a recommended course of action. Remember that cross-examination is not personal. It is the forensic expert's job to stay focused, professional, and respectful at all times. Maintaining professional integrity is paramount.

Defense attorneys can challenge many different aspects of the analysis. They can challenge qualifications, knowledge base, and experience. They can question whether their client(s) had legitimate access to the scene. They can challenge the validity and source of the evidence. Most often, they will challenge the science or some fault or deficiency in the analysis. Fingerprint analysis is especially vulnerable to questions about the following topics:

- Erroneous identifications
- The lack of a probability model to support a conclusion
- Absolute conclusions ("100% match", "to the exclusion of all others")
- Familiarity with publications critical to the fingerprint sciences
- Minimal error rate research
- Cognitive bias in the examination process
- Lack of documentation supporting one's conclusions

All these topics can be answered truthfully and succinctly if the fingerprint examiner stays current in his or her field. When the cross-examination phase is complete, and if there are no more questions from either attorney, the expert witness will be dismissed and can exit the courtroom.

19.9 The Daubert Trilogy

Several landmark court cases have resulted in precedents that have changed how the judicial system approaches forensic testimony. A *precedent* is a rule developed as a result of court case. The court's ruling becomes *case law*, and all court cases to follow are subject to the precedent. The first judicial decision to affect how fingerprint examiners testify in court was the result of *Frye v. United States* in 1923.[7] The question that arose in court was whether an early form of the polygraph test was reliable enough to be admitted as evidence in court. The polygraph testimony was not admitted into court because, as the judge determined, it had not gained general acceptance in the relevant scientific community. It was therefore not considered reliable evidence. A precedent was established, and all scientific testimony to follow in the United States was held to the *Frye standard*. The following is an excerpt from this decision:

> Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force

> of the principle must be recognized, and while the courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.[7]

The Frye standard is also known as the *rule of general acceptance*. It states that scientific testimony is admissible in a court of law only if it is generally accepted by the relevant scientific community.

Until 1993 in the United States, fingerprint testimony was accepted according to the Frye standard. Fingerprint analysis had been around since the early 1900s and was accepted by the relevant forensic science community. A court decision in 1993 changed the course of forensic fingerprint analysis. The Daubert family sued Merrell Dow Pharmaceuticals, Inc. alleging that the company's ant nausea drug caused birth defects.[8] Testimony from various doctors and medical researchers brought into question whether the Frye standard was adequate to determine admissibility of scientific methodology.

The court's decision in this matter became known as the *Daubert standard*, which is a benchmark for determining the validity of scientific processes entering the courtroom.

The Daubert standard expands the Frye test of general acceptance. It concludes that scientific testimony should be judged by more rigorous criteria than vague general acceptance. Those criteria are as follows:

1. The science must be generally accepted in the relevant scientific community (Frye Standard).
2. The science must have a known or potential error rate.
3. The science must be testable.
4. The science must be subject to peer review and publication.
5. The science must have existing controls and standards.[8]

If the admissibility of a type of science is in question, there may be a *Daubert hearing*: a short proceeding in court outside of a jury trial to determine whether or not the expert will be allowed to testify to their conclusions. At a Daubert hearing, a multitude of experts may be called to testify to the reliability or fallibility of the science. Approximately 40 of the United States adopted the Daubert standard as of 2017.

Fingerprint analysis has been subjected to Daubert hearings since Daubert's inception. This is because there was no known error rate for the fingerprint comparison methodology in the 1990s and early 2000s. Over 40 Daubert hearings during this period resulted in all fingerprint evidence passing the Daubert standard's guidelines.

Two more court cases expanded on the Daubert standard, creating what is now known as the *Daubert Trilogy*. In the case of *General Electric Co. v. Joiner*, the court reiterated that the judge would be the "gatekeeper" for admissibility of scientific evidence.[9] In the case of *Kumho Tire Company v. Carmichael*, the Daubert standard was extended to include not only scientific evidence but also technical evidence from nonscientists.[10] In this case, the technical evidence in question was the testimony of an engineer. The three cases—Daubert, Joiner, and Kumho Tire—are collectively known as the "Daubert trilogy."

In comparison with the Daubert decision in the United States, the United Kingdom's Law Commission published a similar recommendation with regard to the admissibility of scientific evidence in 2011.[11] This is known as the *common law admissibility test*. The commission recommended that the trial judge take into consideration the following factors when determining admissibility:

- The quality of the underlying science and methodologies
- The statistical significance or reliability of the method
- The accuracy of methods or tests utilized
- Whether the science, method, or test has been peer reviewed
- Whether the expert is testifying in his or her specific field of expertise
- "The completeness of the information which was available to the expert, and whether the expert took account of all relevant information in arriving at the opinion"[11]

These guidelines closely resemble those of the Daubert decision, and reflect an increasing drive toward scientific vigor, accuracy, and transparency in the field of fingerprint analysis.

19.10 Testimony in a Modern Forensic Landscape

The paradigm shifts of the past and the current research trends in the forensic sciences influence how the modern forensic scientist testifies. What hasn't changed is that the successful expert witness values professional and personal integrity; is educated in the scientific basis of the examination process; and can successfully explain those scientific concepts to the layperson. Explanations should be honest, clear, and concise so that jurors are able to learn about the science and methodology. Jurors want to understand the science so they can comprehend the expert's conclusions and opinions.

The future of forensic expert testimony will be influenced by the research happening now. Fingerprint examiners will testify to potential error rates based on completed and ongoing studies. Statistical analyses and probability models may soon be the norm in the field of fingerprint analysis. Transparency and documentation in every step of the ACE-V process will become standard, leaving each independent fingerprint examination open to necessary scrutiny. As the forensic sciences continue to develop, it is necessary to keep up with those advancements and innovations in order to speak intelligently about them in a court of law.

19.11 I Had a Case: The Assassination of President John F. Kennedy

See Appendix E for historical fingerprint expert testimony from the Warren Commission Hearings held to investigate the 1963 assassination of President John F. Kennedy.[12]

19.12 Chapter Summary

An expert witness is someone who knows more about a particular topic than the average person due to experience, training, and education. An expert in a particular field may testify to an opinion based on the results of his or her analysis. Testimony requires the expert witness to teach the jury about his or her science. An effective expert witness speaks with appropriate volume, makes eye contact with jurors, acts naturally, does not display nervous gestures, exudes confidence and competence, and is passionate about the topic presented.

A pretrial conference is a meeting with an attorney during which the expert explains qualifications, analyses, results, conclusions, the scientific basis for conclusions, and any other information relevant to the case. The three main phases of testimony are the qualifying questions phase, direct examination, and cross-examination.

The Frye standard, known as the rule of general acceptance, states that a science is admissible in a court of law if it is generally accepted by the relevant scientific community. The Daubert standard revised Frye to also require scientific testimony to have a calculable error rate, be testable, be subject to publication and peer review, and maintain controls and standards. The Joiner decision augmented the Daubert decision by stating that the judge is the "gatekeeper" for the admissibility of scientific testimony. The Kumho Tire decision revised Daubert to include not only scientific testimony but also technical testimony. The United Kingdom's Law Commission also published a set of guidelines regarding the admissibility of scientific evidence known as the common law admissibility test.

19.13 Review Questions

1. Define "expert witness."
2. Describe FRE 702 and explain how it relates to fingerprint testimony.
3. What are the rights guaranteed by the Sixth Amendment?
4. List five qualities of an effective teacher.
5. Define a latent fingerprint as you would in court.
6. Write your own qualifying questions and answers.
7. What is a pretrial conference, and why is it important?
8. What are the three main phases of testimony?
9. What is the Frye standard?
10. What is the Daubert standard, and how does it impact the forensic scientist? How does the Daubert standard differ from the common law admissibility test?

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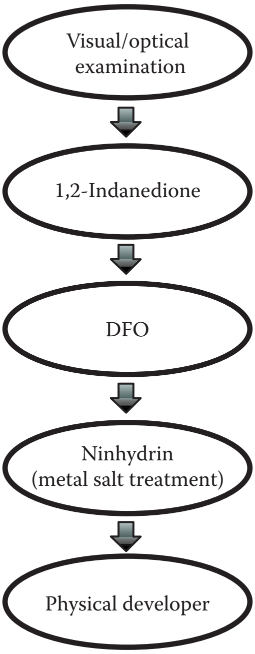
Appendix A: Sequential Processing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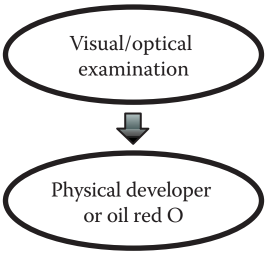
1,2-Indanedione
DFO
Ninhydrin (metal salt treatment)
Physical developer

Processing sequence for porous, dry substrates.


Visual/optical examination
Physical developer or oil red O

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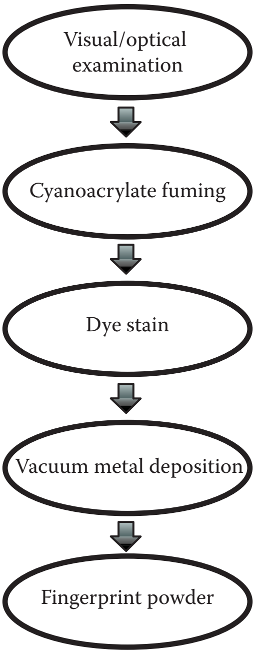
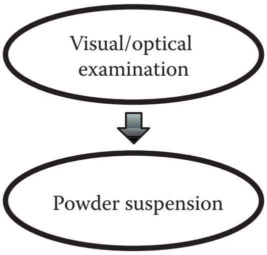
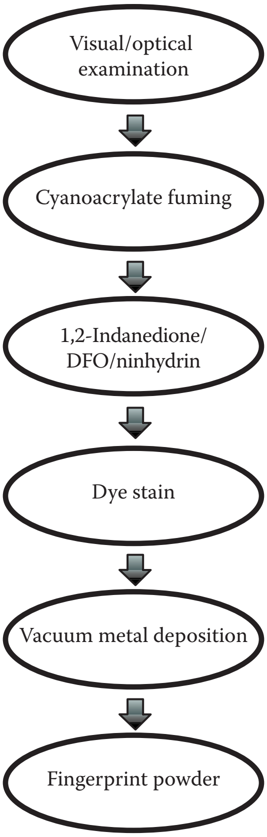

Visual/optical examination
Cyanoacrylate fuming
Dye stain
Vacuum metal deposition
Fingerprint powder

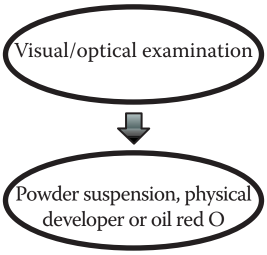
Processing sequence for nonporous, dry substrates.


Visual/optical examination
Powder suspension

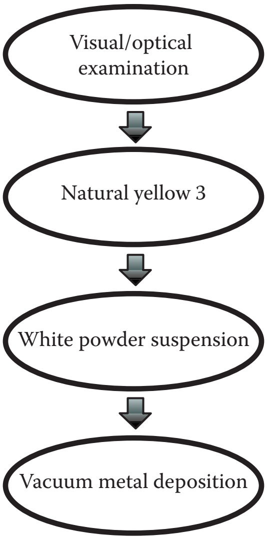
Processing sequence for nonporous, wet substrates.


Visual/optical examination
Cyanoacrylate fuming
1,2-Indanedione/ DFO/ninhydrin
Dye stain
Vacuum metal deposition
Fingerprint powder

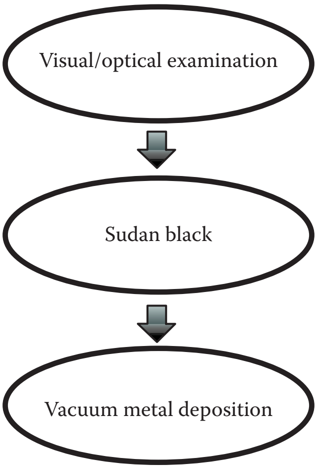
Processing sequence for semiporous, dry substrates.


Visual/optical examination
Powder suspension, physical developer or oil red O

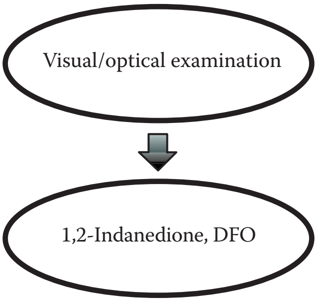
Processing sequence for semiporous, wet substrates.


Visual/optical examination
Natural yellow 3
White powder suspension
Vacuum metal deposition

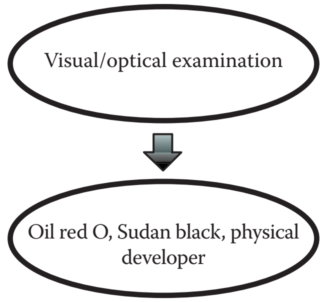
Processing sequence for greasy/oily latent prints on nonporous, dark or patterned substrates.


Visual/optical examination
Sudan black
Vacuum metal deposition

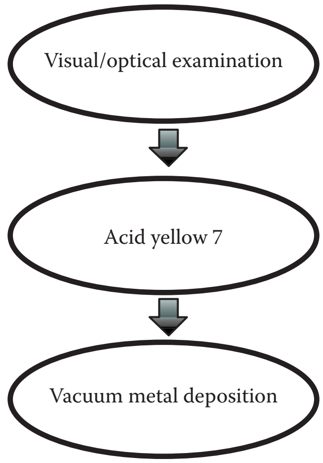
Processing sequence for greasy/oily latent prints on nonporous, light colored substrates.


Visual/optical examination
1,2-Indanedione, DFO

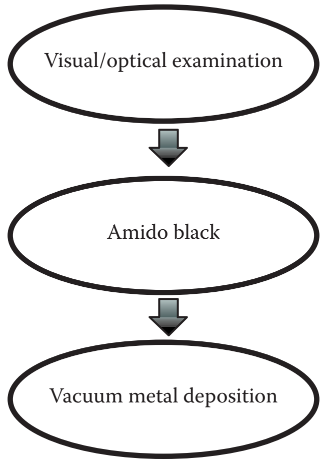
Processing sequence for greasy/oily latent prints on porous, dark colored substrates.


Visual/optical examination
Oil red O, Sudan black, physical developer

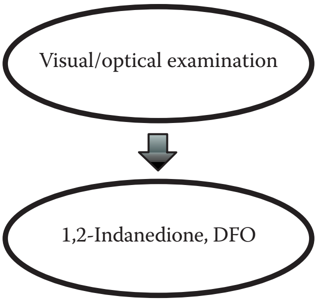
Processing sequence for greasy/oily latent prints on porous, light colored substrates.


Visual/optical examination
Acid yellow 7
Vacuum metal deposition

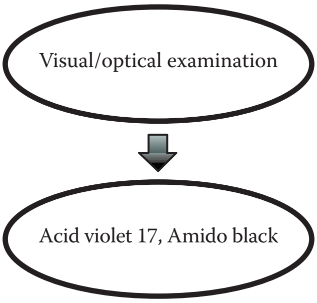
Processing sequence for bloody latent prints on nonporous, dark colored substrates.


Visual/optical examination
Amido black
Vacuum metal deposition

Processing sequence for bloody latent prints on nonporous, light colored substrates.


Visual/optical examination
1,2-Indanedione, DFO

Processing sequence for bloody latent prints on porous, dark colored substrates.


Visual/optical examination
Acid violet 17, Amido black

Processing sequence for bloody latent prints on porous, light colored substrates.

Appendix B: Latent Print Reagent Formulations and Processes (In Alphabetical Order)

All reagents should be stored in clearly labeled glass containers away from direct sunlight. Wherever possible, the least toxic and/or flammable solution is presented. Personal protective equipment should be worn at all times when working with chemical reagents regardless of toxicity or flammability.

Acid Violet 17[1]

Fixing solution

20 g	5-sulfosalicylic acid
1 l	Distilled water

1. Mix 5-sulfosalicylic acid with distilled water in a beaker over a magnetic stirrer.
2. Immerse the evidentiary item in the fixing solution for 5 or more minutes.

Working solution

1 g	Acid violet 17
250 ml	Ethanol
50 ml	Acetic acid
700 ml	Distilled water

3. Mix the working solution in a beaker over a magnetic stirrer for 5 min.
4. Immerse the evidentiary item in the working solution for 3 or more minutes.
5. Rinse with distilled water.
6. Dry at room temperature.

De-staining solution

250 mL	Ethanol
50 ml	Acetic acid
700 ml	Distilled water

7. Immerse the item in a de-staining solution (given earlier) to lessen background staining.

Acid Yellow 7[1]

Fixing solution

20 g	5-sulfosalicylic acid
1 l	Distilled water

1. Mix 5-sulfosalicylic acid and distilled water in a beaker over a magnetic stirrer.
2. Immerse the evidentiary item in the fixing solution for 5 or more minutes.

Working solution

1 g	Acid yellow 7
250 ml	Ethanol
50 ml	Acetic acid
700 ml	Distilled water

3. Mix the working solution in a beaker over a magnetic stirrer for 1 min.
4. Immerse the evidentiary item in the working solution for 5 min.
5. Rinse in distilled water.
6. Dry at room temperature.

De-staining solution

250 ml	Ethanol
50 ml	Acetic acid
700 ml	Distilled water

7. Immerse in a de-staining solution of either 10% bleach or the de-staining solution (given earlier) to lessen background staining.

Amido Black[1]

Fixing solution

20 g	5-sulfosalicylic acid
1 l	Distilled water

1. Mix 5-sulfosalicylic acid and distilled water in a beaker over a magnetic stirrer.
2. Immerse the evidentiary item in the fixing solution for 5–6 min.

Working solution

1 g	Amido black
250 ml	Ethanol
50 ml	Acetic acid
700 ml	Distilled water

3. Mix the working solution in a beaker over a magnetic stirrer for 5 min.
4. Immerse the evidentiary item in the working solution for 3–4 min or spray the item and let it run over the fixed fingerprints.
5. Rinse in distilled water.
6. Dry at room temperature.

De-staining solution

250 ml	Ethanol
50 ml	Acetic acid
700 ml	Distilled water

7. Immerse the item in a de-staining solution (given earlier) to lessen background staining.

Ardrox[2]

Working solution

10 ml	Ardrox
1 l	Methanol

1. Mix the aqueous Ardrox solution with methanol in a beaker over a magnetic stirrer.
2. Dip or spray the superglue-processed evidentiary item with the working solution.
3. Rinse gently under running tap water.
4. Hang to dry in a fume hood.
5. Observe the fluorescence under UV illumination (365–380 nm) using UV protective goggles, violet/blue illumination (435–445 nm) with yellow goggles, and/or blue illumination (445–480 nm) with orange goggles.

Basic Yellow 40/Brilliant Yellow 40 (BY 40)[3]

Working solution

2 g	BY 40
1 l	Ethanol

1. Mix the BY 40 in ethanol in a beaker over a magnetic stirrer.
2. Dip or spray the superglue-processed evidentiary item with the working solution.
3. Rinse gently under running tap water.
4. Hang to dry in a fume hood.
5. Observe the fluorescence under UV illumination (~365 nm) using UV protective goggles.

DFO[4]

Stock solution

0.25 g	DFO (1,8-Diazafluoren-9-one)
40 ml	Methanol
20 ml	Acetic acid

1. Dissolve the DFO in methanol and acetic acid in a beaker over a magnetic stirrer for approximately 20 min until completely dissolved.

Working solution

60 ml	DFO stock solution
940 ml	HFE7100

2. Slowly add the HFE7100™ solvent to the stock solution.
3. Dip or spray the evidentiary item until it is saturated.
4. Hang the item to dry in a fume hood.
5. When dry, heat the item in an incubator at 100°C for 20 min.
6. View the item through a red filter or using red goggles under green light (530–570 nm) using an alternate light source or laser.

1,2 Indanedione[5]

Zinc chloride stock solution

0.4 g	Zinc chloride
10 ml	Ethanol
1 ml	Ethyl acetate
190 ml	HFE 7100™

Working solution

0.8 g	1,2-indanedione
79 ml	Ethyl acetate
10 ml	Glacial acetic acid
80 ml	Zinc chloride stock solution
930 ml	HFE 7100™

1. Dissolve the indanedione completely in ethyl acetate and glacial acetic acid in a beaker over a magnetic stirrer.
2. When the indanedione is completely dissolved, add the zinc chloride stock solution.
3. Slowly add the HFE7100™.
4. Dip or spray the evidentiary item with the working solution until it is saturated.
5. Dry in a fume hood.
6. Heat in an incubator at 100°C for 20 min.
7. Document visible fingerprints.
8. View the item through a red filter or using red goggles under green light (530–570 nm) using an alternate light source or laser.

Natural Yellow 3[6]

Working solution

1.0 g	Natural yellow 3
100 ml	Ethanol
50 ml	Distilled water

1. Dissolve the natural yellow 3 in ethanol in a beaker over a magnetic stirrer.
2. Add the distilled water and stir vigorously for 5 min until a clear solution is produced.
3. Dip the evidentiary item into the working solution for approximately 10 s.

4. Rinse gently under running tap water.
5. Hang to dry in a fume hood.
6. Observe the fluorescence under blue to blue-green illumination (420–540 nm) using yellow/orange goggles.

Ninhydrin[5]

5 g	Ninhydrin crystals
45 ml	Ethanol
2 ml	Ethyl acetate
5 ml	Acetic acid
1 l	HFE 7100™

1. Dissolve the ninhydrin crystals in ethanol, ethyl acetate, and acetic acid in a beaker over a magnetic stirrer.
2. When the ninhydrin is completely dissolved, slowly add the HFE7100™ solvent.
3. Dip or spray the evidentiary item until it is saturated.
4. Hang to dry in a fume hood.
5. Label and photograph the visible fingerprints.

Oil Red O[5,7]

Working solution (non methanolic)

0.05 g	Oil red O
100 ml	Propylene glycol

1. Dissolve the oil red O in propylene glycol in a beaker over a magnetic stirrer at 95°C.
2. Cool the solution and filter off the un-dissolved oil red O.
3. Immerse the evidentiary item in the oil red O working solution for 15 min, agitating for ~30 s.
4. Rinse in deionized water (optional).
5. Hang to dry in a fume hood.

Physical Developer[5,8]

Maleic acid solution

30 g	Maleic acid
1 l	Distilled water

1. Dissolve maleic acid in distilled water in a beaker over a magnetic stirrer.
2. Pour the resulting solution into a clean, nonmetallic tray that has been rinsed with distilled water.
3. Immerse the evidentiary item in the maleic acid solution for 5 min or until bubbles no longer form on the item.

PD (physical developer) stock solutions

Redox solution

900 ml	Distilled water
30 g	Ferric nitrate
80 g	Ferrous ammonium sulfate
20 g	Citric acid

1. Mix the ferric nitrate into the distilled water in a beaker over a magnetic stirrer.
2. Add the ammonium ferrous sulfate.
3. Add the citric acid.
4. Store this stock solution away from light and heat.

Surfactant solution

1 l	Distilled water
4 g	*N*-dodecylamine acetate
4 ml	Tween® 20 detergent solution (surfactant)

5. While stirring the distilled water, add the *N*-dodecylamine acetate in a beaker over a magnetic stirrer.
6. Add Tween® 20 detergent solution and mix thoroughly.

Silver nitrate solution

50 ml	Distilled water
10 g	Silver nitrate

7. While stirring the distilled water, add the silver nitrate in a beaker over a magnetic stirrer.
8. Stir until completely dissolved.
9. Store this stock solution away from light and heat.

PD working solution

10. While stirring the redox solution in a large beaker over a magnetic stirrer, add 40 ml of the surfactant solution.

11. Stir for 2 min.
12. Add the silver nitrate solution.
13. Stir for 2 min.
14. Pour the resulting solution into a clean, nonmetallic tray that has been rinsed with distilled water.
15. Following the maleic acid wash, immerse in the PD working solution and agitate until dark gray friction ridges are observed.
16. Rinse the item with tap water.
17. Optional: Immerse in a solution of 1:1 bleach to water for 2–3 min to decrease background staining.
18. Hang to dry in a fume hood.

Powder Suspension

Black fingerprint powder
    Liquinox™, Triton X-100-ethylene glycol* or Tween 20™ detergent
    Distilled water

1. Mix equal amounts of detergent and distilled water.
2. Add black fingerprint powder until the solution is the consistency of paint.
3. Paint the solution onto the adhesive substrate using a camel hairbrush.
4. Let the solution sit on the surface for 30–60 s.
5. Rinse the item under running tap water.
6. Hang to dry in a fume hood.

Rhodamine 6G

Working solution

0.005–0.05 g	Rhodamine 6G
1 l	Methanol or distilled water

1. Dissolve rhodamine 6G in methanol or water in a beaker over a magnetic stirrer.
2. Dip or spray the superglue-processed evidentiary item.
3. If using a higher concentration, gently rinse the item with methanol or water depending on the carrier solvent used.
4. Hang to dry in a fume hood.
5. Observe the fluorescence under blue-green/green illumination (490–550 nm) using orange/red goggles.

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* Triton X-100-ethylene glycol formulation: 25% Triton X-100, 35% ethylene glycol, and 40% deionized water.

Sudan Black (Solvent Black 3)[5]

Working solution

15 g	Sudan black
1 l	Ethanol
500 ml	Distilled water

1. Dissolve Sudan black in ethanol in a beaker over a magnetic stirrer until dissolved.
2. Add distilled water and mix until combined.
3. Soak the evidentiary item in the working solution for approximately 2 min.
4. Rinse gently under running tap water.
5. Hang to dry in a fume hood.

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7. Frick, A.A. et al. 2013. Sequencing of a modified Oil Red O development technique for the detection of latent fingermarks on paper surfaces. *J. Forensic Ident.* 63: 369–385.
8. Yamashita, B. and French, M. 2011. Latent print development. In the Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST) et al., *The Fingerprint Sourcebook*, U.S. Department of Justice, Office of Justice Programs. Washington, DC: National Institute of Justice.

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Appendix C: Potential Hazardous Effects of Common Fingerprint Powders and Chemical Reagents[1–20]

Reagent	Skin	Eyes	Ingestion	Inhalation	Environment
Cyanoacrylate (superglue)	Bonds immediately and may cause burns	Irritation, redness, pain, possible bonding	Nontoxic	Irritation, coughing, shortness of breath	
Ardrox	Dermatitis, irritation	Irritation, redness	Irritation, vomiting, diarrhea, aspiration pneumonia if vomited	Irritation, breathing difficulty	Nonbiodegradable
Rhodamine 6G (Basic Red 1)	Irritation	Irritation, possibly severe	Toxic	Irritation, lung damage with long-term exposure to dust	
Ninhydrin	Irritation	Irritation, redness	Harmful	Irritation	Hazardous
1,2 Indanedione	Irritation	Severe irritant, redness, pain	Toxic	Irritating, coughing, sore throat, wheezing	Long-term adverse effects to marine environment
DFO (1,8-diazafluoren-9-one)	Itching, rash	Irritation, redness, pain	Harmful	Cough, wheezing, respiratory distress	Toxic to aquatic life
Silver nitrate	Burns	Burns	Burns, lethal dose is 2 g	Burns, severe irritation, couching, breathing difficulty, possible coma	Toxic to aquatic life
Physical developer	Harmful, irritant	Severe irritant	Irritant, vomiting, diarrhea		Toxic to aquatic life
Lightning® Black Fingerprint Powder	Redness	Irritation	Nontoxic	Chronic, coughing, sneezing	

(*continued*)

Reagent	Skin	Eyes	Ingestion	Inhalation	Environment
Lightning® Bichromatic Fingerprint Powder (aluminum based)	Redness	Irritation			
Redwop fluorescent powder		Irritation, redness, pain	Low toxicity	Irritation, coughing, shortness of breath	
Small particle reagent (molybdenum disulfide dispersion)	Possible irritation	Irritation		Irritation	
Crystal violet	Irritation, burning, itching	Severe irritation, possibly irreversible damage	Toxic, vomiting, diarrhea, abdominal distress	Irritation	
Aqueous Amido Black	Irritation, burns, rash	Irritation, redness, pain	Toxic	Irritation, damage to respiratory tract, coughing, shortness of breath	Hazardous
3M Novec™ Engineered Fluid HFE-7100 (fluorocarbon ether)			Gastrointestinal upset		Harmful to aquatic life
Acetic acid	Severe burns	Severe burns, irreversible damage	Burns, severe and permanent damage to digestive tract, severe pain, nausea, vomiting, diarrhea, shock	Burns, bronchitis, dental erosion	
Ethyl acetate	Irritation	Irritation	Irritation	Irritation	
Ethanol	Moderate irritation	Severe irritation	Irritation, nausea, vomiting, diarrhea	Nausea, headache, dizziness in high concentrations	
Methanol	Irritation, absorption could lead to visual disturbances	Painful sensitization to light, irritant	May be fatal, may lead to blindness	Toxic, may lead to visual impairment or blindness	
Petroleum ether	Irritation	Irritation	Carcinogenic; central nervous system depression	Central nervous system effects	Harmful to aquatic life

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4. Ninhydrin: MSDS. 2011. Safariland MSDS Retrieval System.
5. 1,2 Indanedione: MSDS. 2011. Safariland MSDS Retrieval System.
6. DFO (1,8-Diazafluoren-9-One): MSDS. 2011. Safariland MSDS Retrieval System.
7. Silver nitrate: MSDS Acc.# 20810. 2008. Fisher Scientific.
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Appendix D: Curriculum Vitae (CV)

It is important for the professional forensic scientist to create a scientific resume known as a curriculum vitae (CV). "Curriculum vitae" is Latin and translates roughly to "the course of your life." A CV is, in fact, a professional autobiography. It is used to determine the scientist's credentials when testifying in a court of law. It may also be used to apply for employment in the forensic field. It is referred to as a "living document," because it will grow with the forensic scientist's career. As the forensic scientist attends trainings, gains experience, publishes scientific research, and presents at conferences or meetings, these experiences are added to the CV.

While the CV resembles a resume, there are several differences between the content of the two documents. A resume is no more than two pages long and contains only the individual's contact information, educational credentials, and previous employment. It may also contain professional references. A CV is longer and contains more detail about the scientist's professional experience. It should contain only relevant scientific or technical experience. For example, an individual who worked as a lifeguard at a swimming pool might include that experience on a resume, but not on a CV. Conversely, someone who worked at a microbiology laboratory at a university may include that experience in his or her CV. The format, font and bullet points should be simple and easy to read. Elaborate formatting distracts from the content of the CV and makes it difficult for the reader to locate relevant information. All information should be presented in reverse chronological order; the most recent experience is listed first.

Once the CV has been prepared, at least one colleague or mentor should proofread it. As the CV is your professional autobiography, it should be grammatically and stylistically accurate. It is often the first impression the forensic scientist will make on a future employer, prosecutor, defense attorney, or opposing witness. Below is a list of the categories that may be included in a forensic scientist's CV.

- Name, current contact information
- Education (degrees earned, universities attended, locations of universities, dates of graduation)
- Employment/experience (voluntary and paid)
- Professional development/training (titles, dates, locations, trainers, and duration of each training)
- Presentations/publications
- Association memberships/affiliations
- Academic/professional distinctions/recognition
- Equipment/processes
- Court appearances
- Number of cases examined/fingerprints compared (can be approximated)

- Specialized or proprietary software/equipment/processes utilized
- Other relevant categories: security clearances, languages, basic software proficiency

A simple Internet search will provide many examples of CVs formatted in different styles. Colleagues, professors, supervisors, and mentors may also be able to provide examples. The author's CV is included below as a sample for content and formatting. (The author's mobile number and email have been changed for privacy purposes.)

Curriculum Vitae

Hillary Moses Daluz
Forensic Scientist

415-555-1870 mobile
email@gmail.com

Experience:

- Instructor, Tri-Tech Forensics (03/2015–present)
    - Developing and teaching the following training programs for criminal justice and forensics professionals nationwide: "Forensic Science Courtroom Testimony Workshop" (24 hours), "Courtroom Testimony for Fingerprint Examiners" (24 hours), "Sensitive Site Exploitation—Battlefield Forensics" (40 hours), and "Processing Improvised Explosive Devices for Fingerprint Evidence" (40 hours).
- Forensic Specialist, Forensic Identification Services, San Francisco, CA (07/2003–present)
    - Developing, examining, comparing, analyzing, and reporting fingerprints on a variety of surfaces using highly technical and advanced laboratory equipment and chemicals.
    - Recording known fingerprints utilizing powder and ink.
    - Analyzing complex fingerprint cases; imperfect and partial latent fingerprint impressions that contain only the minimum number of points necessary to make an identification and partial latent fingerprint impressions.
    - Performing complex digital enhancements of prints utilizing Adobe Photoshop.
    - Preparing written laboratory notes, reports, and invoices based on examinations.
    - Complex crime scene reconstruction.
- Senior Latent Print Technician, American Systems, Lorton, VA [DoD Clearance] (06/2013–08/2014)
    - Supervising and managing a squad of ten Latent Print Technicians responsible for analyzing complex fingerprint cases and processing complex materials associated with Improvised Explosive Devices (IEDs).
    - Acting Deputy Program Manager in the absence of the Deputy Program Manager/Shift Lead.
    - Developing, examining, analyzing, and reporting fingerprints on a variety of surfaces using highly technical and advanced laboratory equipment and chemicals to include the use of forensic light sources and RUVIS.
    - Communicating with U.S. Government representatives via oral and written products by serving as a technical expert and liaison.

  - Examining recovered physical evidence from Improvised Explosive Devices (IEDs) related evidence recovered by U.S. Government agencies for the detection of latent prints, to include assessing potential forensic significance of DNA and trace evidence and determine pertinent forensic examinations to further the mission of ensuring homeland security.
  - Recognizing developed latent prints during each processing method in order that they might be preserved for digital capture, search, comparison, and analysis using an Automated Fingerprint Identification System (AFIS).
  - Maintaining proper chain of custody of all forensic materials under examination.
  - Preparing written laboratory reports based on examinations utilizing proprietary software to include detailing observations, the results of examinations, and the conclusions of forensic analysis.
  - Coordinating and conducting training and mentoring for developmental level specialists with a wide variety of education and experience.
  - Providing quality control for the casework and detailed case notes and paperwork produced during evidence examinations.
- Lecturer, Forensic Sciences Department, Chaminade University of Honolulu, Honolulu, HI (11/2010–06/2013)
  - Teaching the following courses at the undergraduate and graduate level: Fingerprint Analysis, Fingerprint Analysis Laboratory, Crime Scene Investigations, Crime Scene Investigations Laboratory, Courtroom Testimony, Physical Forensic Sciences, and Senior Seminar.
  - Acquiring an Automated Fingerprint Identification System (AFIS) for educational purposes.
  - Advising students and directing graduate-level research projects.
- Latent Print Examiner, Ideal Innovations Inc., Joint Expeditionary Forensic Facility 3, Camp Victory—Baghdad, Iraq. [DoD Secret Clearance] (04/2009–06/2010)
  - Developing, examining, comparing, analyzing, and reporting fingerprints on a variety of surfaces using highly technical and advanced laboratory equipment and chemicals.
  - Performing complex digital enhancements of prints by searching, comparing, and analyzing prints using an Automated Fingerprint Identification System (AFIS).
  - Preserving and analyzing evidence while maintaining chain of custody and integrity of the evidence.
  - Analyzing complex fingerprint cases, including imperfect and partial latent fingerprint impressions that contain only the minimum number of points necessary to make an identification.
  - Preparing written laboratory notes and reports based on examinations.
  - Teaching United States soldiers, sailors, airmen, and marines and coalition forces the “Evidence Collection, Packaging and Laboratory Analysis” course as part of the Advanced Sensitive Site Exploitation course.
- Teaching Assistant, “Personal Identification Methods in Forensic Science,” Forensic Science Graduate Group, University of California, Davis, CA (03/2008–06/2008)
  - Assisting with graduate-level forensics course lectures and practical exercises.

  - Providing academic assistance to graduate students in the forensic science department of the University of California, Davis.
  - Grading homework assignments and exams.
- Police Identification Specialist, Hayward Police Department, Hayward, CA (09/2004–09/2006)
  - Developing, examining, comparing, analyzing, and reporting fingerprints on a variety of surfaces using highly technical and advanced laboratory equipment and chemicals.
  - Performing complex digital enhancements of prints and searching, comparing, and analyzing prints using an Automated Fingerprint Identification System (AFIS).
  - Serving as a team member dispatched to crime scenes: collecting, preserving, and analyzing evidence while maintaining chain of custody and integrity of the evidence.
  - Devising new methods and techniques to enhance latent fingerprint examination capabilities.
  - Serving as an expert witness in court proceedings.
  - Preparing and reviewing written laboratory reports, court charts, recommendations, standard operating procedures, and guidelines.
  - Analyzing complex fingerprint cases including imperfect and partial latent fingerprint impressions that contain only the minimum number of points necessary to make an identification and partial latent fingerprint impressions.
  - Left this position in 2006 to attend graduate school.

Education:

- M.S. Forensic Science, University of California, Davis, 2009.
- B.S. Genetics, University of California, Davis, 2003.

Professional Training:

- Cogent Users Group International Conference (Indian Wells, CA, October 2017)
- Unconventional Photographic Imaging Techniques (American Systems: August 2014)
- Improvised Explosive Device (IED) Awareness Training (American Systems quarterly training: 2013–2014)
- Psychology and Investigation of Serial Homicides (American Systems: August 2014) [10 hours]
- Burglary Investigation (American Systems: June 2014) [1 hour]
- Improvised Explosive Device Design and Construction (American Systems: June 2014)
- Overview of Resolution and Printing Technologies for Forensic Photography (American Systems: June 2014)
- Introduction to Firearms and Toolmarks (American Systems: June 2014)
- Management Workshop (American Systems: April 2014)
- History, Design, Nomenclature, and Processing of Foreign Weapons (American Systems: 2014)
- Small Arms Ammunition Firearms Training (American Systems: March 2014)

- Hazmat & Blood borne Pathogens Training (American Systems: January 2014)
- Good Laboratory Practices Training (American Systems: February 2014)
- Doing Business With the Federal Government: Compliance Overview (June 2013)
- Latent Print Technician Training Course (American Systems: June 2013)
- International Association for Identification Conferences (2009–2014)
- Comprehensive Documentation of Bloodstain Evidence at Scenes (Bevel, Gardner and Associates: July 2012)
- California State Division of the International Association for Identification Conferences (2003–2011)
- Forensic Fingerprint Analysis Basics (National Institute of Justice: August 2010)
- Latent Print Identification & Comparison (Mike Stapleton, Sacramento Regional Training Center. Sacramento, CA, 2008)
- DOJ Basic Practical Microscopy (California Department of Justice: 2008)
- American Academy of Forensic Sciences Conference (2008)
- Firearms Safety Workshop (California Department of Justice: October 2007)
- Laboratory Leadership (University of California, Davis: August 2007)
- From Fingerprint Examination to Fingerprint Statistics (IAI Educational Conference: July 2007)
- Latent Print Comparisons (California Criminalistics Institute: August 2006)
- Advanced Palm Print Comparison Techniques (Ron Smith and Associates: March 2006)
- National Academy of Sciences Colloquium: Forensic Science and the Law (2005)
- Basic Crime Scene Investigation (Sacramento Sheriff's Department: January 2005)
- Grants 101: Professional Grant Proposal Writing (San Francisco State University: March 2005)
- Firearms Investigation Training (Bureau of Alcohol, Tobacco, Firearms and Explosives: June 2005)
- Automated Latent Palm Prints System (Bay Counties Identification Officers Association: February 2004)
- Basic Evaluation and Comparison of Latent Fingerprint Workshop (Florida Division of the International Association for Identification: October 2003)

Presentations:

- *Courtroom Testimony for Fingerprint Examiners*. 24-hour professional training conducted for Tri-Tech Forensics. (Boca Raton Police Department, Boca Raton, FL, April 2018)
- *Forensic Science Courtroom Testimony*. 16-hour professional training conducted for Tri-Tech Forensics. (San Diego Police Department, San Diego, CA, January 2018)
- *The View From the Dark Side: Issue Spotting From a Defense Perspective*. 2 1/2-hour presentation for the Cogent Users Group International Meeting. (Indian Wells, CA, October 2017)
- *Forensic Science Courtroom Testimony Workshop*. 24-hour professional training conducted for Tri-Tech Forensics. (Phoenix Police Department, Phoenix, AZ, October 2017)
- *It's All Greek to Me! Explaining Scientific Concepts to the Layperson*. 4-hour courtroom testimony workshop conducted at the annual conference for the Missouri

Division of the International Association for Identification. (Springfield, MO, October 2017)

- *Recovering Fingerprints from Improvised Explosive Devices (IEDs).* 2-hour presentation at the annual conference for the Missouri Division of the International Association for Identification. (Springfield, MO, October, 2017)
- *Courtroom Testimony for Fingerprint Examiners.* 24-hour professional training conducted for Tri-Tech Forensics. (Round Rock Police Department. Round Rock, TX, September, 2017)
- *It's All Greek to Me! Explaining Scientific Concepts to the Layperson.* 4-hour courtroom testimony workshop conducted at the annual conference for the International Association for Identification. (Atlanta, GA, August, 2017)
- *Forensic Science Courtroom Testimony Workshop.* 24-hour professional training conducted for Tri-Tech Forensics. (Pembroke Pines Police Department, Pembroke Pines, FL, July 2017)
- *Forensic Science Courtroom Testimony Workshop.* 24-hour professional training conducted for Tri-Tech Forensics. (Miami Dade Medical Examiner's Office, Miami, FL, January, 2017)
- *Courtroom Testimony for Fingerprint Examiners.* 24-hour professional training conducted for Tri-Tech Forensics. (St. Lucie County Sheriff's Department, Fort Pierce, FL, January 2017)
- *Sensitive Site Exploitation—Battlefield Forensics.* 40-hour professional training conducted for Tri-Tech Forensics. (7th Special Forces Group, Eglin AFB, FL, October 2016)
- *Forensic Science Courtroom Testimony Workshop.* 24-hour professional training conducted for Tri-Tech Forensics. (Miami Police Department, Miami, FL, June 2016)
- *Forensic Science Courtroom Testimony Workshop.* 24-hour professional training conducted for Tri-Tech Forensics. (City of Concord Police Department, Concord, CA, January 2016)
- *Forensic Science Courtroom Testimony Workshop.* 24-hour professional training conducted for Tri-Tech Forensics. (Davie Police Department, Davie, FL, August 2015)
- *Captivating the Jury.* 1-hour presentation at the annual conference of the International Association for Identification. (July 2015)
- Weekly forensic training lunches—topics included: Courtroom Testimony, Latent Print Comparisons, Palm Print Comparisons, Latent Print Sufficiency, Biometrics, Battlefield Forensics, curriculum vitae, etc. (American Systems: June 2013 to July 2014)
- *Battlefield Forensics*, 3-hour presentation, annual meeting of the California Division of the International Association for Identification. (July 2010)

Publications:

- Daluz, Hillary Moses. 2014. *Fundamentals of Fingerprint Analysis.* CRC Press: Boca Raton, FL.
- Daluz, Hillary Moses. 2014. *Fingerprint Analysis Laboratory Workbook.* CRC Press: Boca Raton, FL.
- *A critical comparison of black fingerprint powder formulations to improve latent fingerprint clarity and contrast on common substrates.* Hillary Moses. Masters of

Science Thesis. Forensic Science Graduate Group. University of California, Davis. June, 2009.

- *A genome scan of a four-way tilapia cross supports the existence of a quantitative trait locus for cold tolerance on linkage group 23*. Thomas Moen, Jeremy Agresti, Avner Cnaani, Hillary Moses, Thomas Famula, Gideon Hulata, Graham Gall & Bernie May. Aquaculture Research, 2004 (35): 893–904.

Professional Recognition:

- Presented with the American Systems "Culture and Values Award" for formulating comprehensive training programs for staff, improving the efficiency, accuracy, and general forensic knowledge of the employees in attendance (American Systems: June 2014).

Latent Print Processing Techniques Utilized:

- Reflective Ultraviolet Imaging System (RUVIS)
- Fluorescent light sources
- Cyanoacrylate fuming and vacuum chambers
- Adhesive-side powders and SPR
- Fingerprint powders (granular, magnetic, metallic, fluorescent)
- Fluorescent dye stains (Rhodamine 6G, Ardrox, RAM, MBD)
- Processing porous substrates (1,2-indanedione, DFO, ninhydrin, physical developer)

Professional Affiliations:

- International Association for Identification (2003–present)
- California Association of Criminalists (2006–present)
- California State Division of the International Association for Identification (2003–2016)
  - Science and Practices Committee [Chairperson] (2009–2012)
- Chesapeake Bay Division of the International Association for Identification (2012–2014)

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Appendix E: Expert Witness Testimony of Sebastian F. Latona, FBI Latent Fingerprint Examiner

Warren Commission Hearings
April 2, 1964
Part IV, p. 1–81 (redacted)

[Swearing in]

The Chairman.

The Commission will be in order.

Mr. Latona, the purpose of today's hearing is to take your testimony and that of Arthur Mandella. Mr. Mandella is a fingerprint expert from the New York City Police Department. We are asking both of you to give technical information to the Commission.

Will you raise your right hand and be sworn?

Do you solemnly swear that the testimony you are about to give will be the truth, the whole truth, and nothing but the truth, so help you God?

Mr. Latona.

I do.

The Chairman.

You may be seated. Mr. Eisenberg will conduct the examination.

[Qualifying Questions]

Mr. Eisenberg.

Mr. Latona, could you state your full name and give us your position?

Mr. Latona.

My full name is Sebastian Francis Latona. I am the supervisor of the latent fingerprint section of the identification division of the Federal Bureau of Investigation.

Mr. Eisenberg.

What is your education, Mr. Latona?

Mr. Latona.

I attended Columbia University School of Law, where I received degrees of LL.B., LL.M., M.P.L.

Mr. Eisenberg.

And could you briefly outline your qualifications as a fingerprint expert?

Mr. Latona.

Well, I have been with the Federal Bureau of Investigation for a little more than 32 years. I started in the identification division as a student fingerprint classifier, and since that time I have worked myself up into where I am now supervisor of the latent fingerprint section.

Mr. Eisenberg.

Could you approximate the number of fingerprint examinations you have made?

Mr. Latona.

Frankly, no. There have been so many in that time that I would not be able to give even a good guess.

Mr. Eisenberg.

Would the figure run in the thousands or hundreds?

Mr. Latona.

So far as comparisons are concerned, in the millions.

Mr. Eisenberg.

Have you testified in court?

Mr. Latona.

I have testified in Federal courts, State courts, commissioners' hearings, military courts, and at deportation proceedings.

Mr. Eisenberg.

Mr. Chief Justice, I ask that this witness be accepted as an expert.

The Chairman.

The witness is qualified.

[History and Background of the Science]

Mr. Eisenberg.

Mr. Latona, could you briefly outline for us the theory of fingerprint identification?

Mr. Latona.

The principle of fingerprint identification is based on the fact primarily that the ridge formations that appear on the hands and on the soles of the feet actually are created approximately 2 to 3 months before birth, on the unborn child, and they remain constant in the same position in which they are formed until the person is dead and the body is consumed by decomposition.

Secondly, the fact that no two people, or no two fingers of the same person, have the same arrangement of these ridge formations, either on the fingers, the palms, or the soles and toes of the feet. Plus the fact that during the lifetime of a person, this ridge formation does not change, it remains constant—from the time it is formed until actual destruction, either caused by voluntary or involuntary means, or upon the death of the body and decomposition.

Mr. Eisenberg.

Mr. Latona, do you have any personal experience indicating the uniqueness of fingerprints?

Mr. Latona.

Yes; I do. My experience is based primarily upon the work which I have actually done in connection with my work with the FBI. I have had the experience of working on one case in particular in which millions of comparisons were actually and literally made with a small portion of a fingerprint which was left on a piece of evidence in connection with this particular case, which was a kidnapping case.

This fragmentary latent print which we developed consisted of approximately seven to eight points. Most fingerprints will have in them an average roughly of from 85 to about 125.

This fragmentary latent print was compared with literally millions of single impressions for the purpose of trying to effect an identification. And we were unable, over a lengthy period while we were making these millions of comparisons, not able to identify these few fragmentary points.

The important thing is simply this; that on the basis of that fragmentary print, it was not possible to determine even the type of pattern that the impression was. Accordingly, we had to compare it with all types of fingerprint patterns, of which there are really four basic types—the arch, tented arch, loop, and whorl. And we are still making comparisons in that case, and we have not been able to identify these few points.

Now, that means simply this—that the theory that we are going on an assumption that people do not have the same fingerprints—and we find it not necessary to compare, say for example, a loop pattern with a whorl pattern, and as there is a possibility that, it is contended by some of these so-called authorities, that maybe the points that you find in a loop may be found in the same arrangement in a whorl—is not true. I think that that case, a practical case we have actually worked on, disproves that theory so strongly in my mind that I am convinced that no two people can possibly have the same fingerprints.

Mr. Eisenberg.

Are palmprints as unique as fingerprints?

Mr. Latona.

Yes

The Chairman.

Approximately how many fingerprints do you have these days?

Mr. Latona.

At the present time, we have the fingerprints of more than 77 million people

[Evidence in the Case: Developing the Fingerprints]

Mr. Eisenberg.

Now, Mr. Latona, I hand to you an object which I will describe for the record as being apparently a brown, homemade-type of paper bag, and which I will also describe for the record as having been found on the sixth floor of the Texas School Book Depository Building near the window, the easternmost window, on the south face of that floor.

I ask you whether you are familiar with this paper bag?

Mr. Latona.

Yes, I am. This is a piece of brown wrapping paper that we have referred to as a brown paper bag, which was referred to me for purposes of processing for latent prints.

Mr. Eisenberg.

And you examined that for latent prints?

Mr. Latona.

Yes; I did.

Mr. Eisenberg.

Mr. Chairman, may I have this admitted into evidence as Commission Exhibit 626?

The Chairman.

It may be admitted.

Mr. Eisenberg.

Mr. Latona, do your notes show when you received this paper bag?

Mr. Latona.

I received this paper bag on the morning of November 23, 1963.

Mr. Eisenberg.

And when did you conduct your examination?

Mr. Latona.

I conducted my examination on that same day.

Mr. Eisenberg.

Now, Mr. Latona, how did you proceed to conduct your examination for fingerprints on this object?

Mr. Latona.

….This was subjected to what is known as the iodine-fuming method, which simply means flowing iodine fumes, which are developed by what is known as an iodine-fuming gun—it is a very simple affair, in which there are a couple of tubes attached to each other, having in one of them iodine crystals. And by simply blowing through one end, you get iodine fumes.

The iodine fumes are brought in as close contact to the surface as possible. And if there are any prints which contain certain fatty material or protein material, the iodine fumes simply discolor it to a sort of brownish color. And of course such prints as are developed are photographed for record purposes.

That was done in this case here, but no latent prints were developed.

The next step then was to try an additional method, by chemicals. This was subsequently processed by a 3% solution of silver nitrate. The processing with silver nitrate resulted in developing two latent prints. One is what we call a latent palmprint, and the other is what we call a latent fingerprint.

Mr. Eisenberg.

Can you briefly explain the action of the silver nitrate?

Mr. Latona.

Silver nitrate solution in itself is colorless, and it reacts with the sodium chloride, which is ordinary salt which is found in the perspiration or sweat which is exuded by the sweat pores.

This material covers the fingers. When it touches a surface such as an absorbent material, like paper, it leaves an outline on the paper.

When this salt material, which is left by the fingers on the paper, is immersed in the silver nitrate solution, there is a combining, an immediate combining of the elements themselves will break down, and they recombine into silver chloride and sodium nitrate. We know that silver is sensitive to light. So that material, after it has been treated with the silver nitrate solution, is placed under a strong light. We utilize a carbon arc lamp, which has considerable ultraviolet light in it. And it will immediately start to discolor the specimen. Wherever there is any salt material, it will discolor it, much more so than the rest of the object, and show exactly where the latent prints have been developed. It is simply a reaction of the silver nitrate with the sodium chloride.

That is all it is.

Mr. Eisenberg.

Do you frequently find that the silver nitrate develops a print in a paper object which the iodine fuming cannot develop?

Mr. Latona.

Yes; I would say that is true, considerably so. We have more success with silver nitrate than we do with the iodine fumes.

The reason we use both is because of the fact that this material which is exuded by the fingers may fall into one of two main types—protein material and salt material. The iodine fumes will develop protein material. Silver nitrate will develop the salt material.

The reason we use both is because we do not know what was in the subject's fingers or hands or feet. Accordingly, to insure complete coverage, we use both methods. And we use them in that sequence: the iodine first, then the silver nitrate. The iodine is used first because the iodine simply causes a temporary physical change. It will discolor, and then the fumes, upon being left in the open air, will disappear, and then the color will dissolve. Silver nitrate, on the other hand, causes a chemical change and it will permanently affect the change. So if we were to use the silver nitrate process first, then we could not use the iodine fumes. On occasion we have developed fingerprints and palmprints with iodine fumes which failed to develop with the silver nitrate and vice versa.

Mr. Eisenberg.

Now, Mr. Latona, looking at that bag I see that almost all of it is an extremely dark brown color, except that there are patches of a lighter brown, a manila-paper brown. Could you explain why there are these two colors on the bag?

Mr. Latona.

Yes. The dark portions of the paper bag are where the silver nitrate has taken effect. And the light portions of the bag are where we did not process the bag at that time, because additional examinations were to be made, and we did not wish the object to lose its identity as to what it may have been used for. Certain chemical tests were to be made after we finished with it. And we felt that the small section that was left in itself would not interfere with the general overall examination of the bag itself.

Mr. Eisenberg.

That is, the small section of light brown corresponds to the color which the bag had when you received it?

Mr. Latona.

That is the natural color of the wrapper at the time we received it.

Mr. Eisenberg.

And the remaining color is caused by the silver nitrate process?

Mr. Latona.

That is correct.

Mr. Eisenberg.

Does paper normally turn this dark brown color when treated by silver nitrate?

Mr. Latona.

Yes; it does. It will get darker, too, as time goes on and it is affected by light.

Mr. Eisenberg.

Returning to the prints themselves, you stated I believe that you found a palmprint and a fingerprint on this paper bag?

Mr. Latona.

That is correct.

Mr. Eisenberg.

Did you find any other prints?

Mr. Latona.

No; no other prints that we term of value in the sense that I felt that they could be identified or that a conclusion could be reached that they were not identical with the fingerprints or palmprints of some other person.

Mr. Eisenberg.

Did you attempt to identify the palmprint and fingerprint?

Mr. Latona.

The ones that I developed; yes.

Mr. Eisenberg.

Were you able to identify these prints?

Mr. Latona.

I—the ones I developed, I did identify.

Mr. Eisenberg.

Whose prints did you find them to be?

Mr. Latona.

They were identified as a fingerprint and a palmprint of Lee Harvey Oswald.

Mr. Latona.

I do.

Mr. Eisenberg.

Mr. Latona, you have handled me three cards, one of which appears to be a standard fingerprint card, and the other two of which appear to be prints of the palms of an individual. All these cards are marked "Lee Harvey Oswald."

Are these the cards which you received from your Dallas office which you just described as being the prints of Lee Harvey Oswald?

Mr. Latona.

They are.

Mr. Eisenberg.

Mr. Latona, do you know how the known samples we have Just marked 627, 628, and 629 were obtained?

Mr. Latona.

How they were obtained?

Mr. Eisenberg.

Yes. Can you tell the process used in obtaining them?

Mr. Latona.

You mean in recording the impressions?

Mr. Eisenberg.

Yes, sir.

Mr. Latona.

Fingerprints are recorded by the use of a printer's ink, heavy black ink, which is first placed on a smooth surface, such as glass or metal, and it is rolled out in a smooth, even film. Then the subject's fingers are brought in contact with the plate by a rolling process, rolling the finger from one complete side to the other complete side, in order to coat the finger with an even film of this heavy ink. Then the finger is brought in contact with a standard fingerprint card and the finger again is rolled from one complete side to the opposite side in order to record in complete detail all of the ridge formation which occurs on the tip of the finger, or the first joint, which is under the nail.

Mr. Eisenberg.

Now, I believe you said you also found a fingerprint of Lee Harvey Oswald on this paper bag, 626.

Mr. Latona.

Yes; I did.

Mr. Eisenberg.

Can you tell us what finger and what portion of the finger of Lee Harvey Oswald you identified that print as being?

Mr. Latona.

The fingerprint which was developed on the paper bag was identified as the right—as the left index fingerprint of Lee Harvey Oswald. I also have a slight enlargement of it, if you care to see it.

Mr. Eisenberg.

You are showing us a true photograph of the actual fingerprint?

Mr. Latona.

As it appeared on the bag, slightly enlarged.

Mr. Eisenberg.

Now, what portion of the left index finger was that, Mr. Latona?

Mr. Latona.

That is the area which is to the left, or rather to the right of the index finger.

Mr. Eisenberg.

On which joint?

Mr. Latona.

On the first joint, which is under the nail.

Mr. Eisenberg.

Is that known as the distal phalanx?

Mr. Latona.

That's right.

Mr. Eisenberg.

So it is the right side of the distal phalanx of the left index finger?

Mr. Latona.

That is correct. Now, that would be looking at an impression made by the finger. If you were to look at the finger, you would raise the finger up and it would be on the opposite side, which would he on the left side of the distal phalanx.

Mr. Eisenberg.

Mr. Latona, could you show us where on the paper bag, Exhibit 626, this left index finger was developed by you?

Mr. Latona.

The left index fingerprint was developed in the area which is indicated by this small red arrow.

[Evidence in the Case: Fingerprint Comparison]

Mr. Eisenberg.

Mr. Latona, could you show us that chart and discuss with us some of the similar characteristics which you found in the inked and latent print which led you to the conclusion that they were identical?

Mr. Latona.

Yes. I have here what are referred to as two charted enlargements. One of the enlargements, which is marked "Inked Left Index Fingerprint. Lee Harvey Oswald" is approximately a 10-time enlargement of the fingerprint which appears on Exhibit 633A. The other enlargement, which is marked "Latent Fingerprint on Brown Homemade Paper Container," is approximately a 10-time enlargement of the latent fingerprint which was developed on the brown wrapping paper indicated by the red arrow, "B."

Mr. Eisenberg.

And that also corresponds to the photograph you gave us, which is now Exhibit 633?

Mr. Latona.

Now, in making a comparison of prints to determine whether or not they were made by the same finger, an examination is made first of all of the latent print.

An examination is made to see if there are in the latent print any points or characteristics which are unique to the person making the determination. In other words, in looking at the latent print, for example, this point, which is marked "1," is a ridge. The black lines are what we term ridges. They were made by the ridge formations on the fingers. That is, when the finger came in contact with the brown paper bag, it left an outline in these black lines on the brown paper bag.

Now, in looking at the latent print in the enlargement you notice, there is one black line that appears to go upward and stop at the point which has been indicated as point No. 1.

Now, looking further we find this point that has been indicated as No. 3. And No. 3 is located—

Mr. Dulles.

Why do you skip 2?

Mr. Latona.

I am going to come to that.

Mr. Dulles.

I see.

Mr. Latona.

I am going to tie these three in. Point No. 3 is above and to the left one ridge removed from—one black line—there is No. 3. Now looking further, we can look over to the right, or rather to the left, and we notice that one ridge removed from No. 3 are two ridges that come together and give you a point which has been indicated as No. 2.

Mr. Eisenberg.

Is that what you might call a bifurcation?

Mr. Latona.

That is referred to, generally speaking, as a bifurcation.

Mr. Eisenberg.

That is No. 2?

Mr. Latona.

And No. 1 is what is referred to as a ridge end. Now, keeping those three points in mind, and the relationship they have to each other, if this print here, the inked print, were made by the same finger which left the print on the brown paper bag, we should be able to find those three points in the same approximate area, having the same relationship to each other.

Now, at this point we have not made a determination of any kind as to whether they are or are not identical. Examining the inked fingerprint, bearing in mind the general formation of this print that we see here, the latent print, we would examine the inked print and that would direct us to this approximate area here. And looking, we find sure enough there is point No. l—or rather there is a point which appears to be the same as point No. 1 here. Bearing in mind how we located points Nos. 2 and 3, we would then check the inked print further and say to ourselves, "If this print were the same, there should be a point No. 2 in exactly the same relationship to No. 1 as there was in this latent print." We look over here one, two, three, four—there is point No. 2.

Mr. Eisenberg.

That point, or that count that you are making, is of ridges between the first and second point?

Mr. Latona.

Between the points, that's right. Then we have over here one, two, three, four. And bearing in mind again how point No. 3 bears a relationship to point No. 2, we should find point No. 3 in the same relative position in the inked print that it occurs in the latent print. Counting over again—one we find a point which could be considered No. 3.

Now, at this time we have coordinated three points. We have tied three points together. On that basis, by themselves, we would not give a definite determination. Accordingly, we would pursue a further examination to determine whether there are other characteristics which occur.

Mr. Dulles.

How many times is that magnified?

Mr. Latona.

This is magnified approximately 10 times.

Mr. Latona.

Then we would pick up point No. 5. We notice point No. 5 is again one of those bifurcations which occurs above and slightly to the left of point No. 3. We also notice that it envelops point No. 1—as we go down further, slightly to the right of point No. 5, we notice that bifurcation envelops point No. 1. We would look around for such a characteristic in the latent print.

If the same finger made those two prints, we have to find point 5. And looking over here we find such a formation, we look at it, and sure enough it envelops point No. 1—exactly the same relationship to each other appears in the latent print and in the inked print. It has the same relationship to point No. 3 that occurs in the latent print as occurs in the inked print. Then we would pick up point No. 4—one, two, three, four.

Mr. Eisenberg.

Again you are counting ridges?

Mr. Latona.

Counting ridges again, from point No. 5 one, two, three, four. There is a so-called ridge end, which occurs above, above and almost slightly to the left of point No. 5, point No. 5 enveloping No. 1. Point No. 5.

Mr. Dulles.

Is 5 a ridge-end?

Mr. Latona.

Five is what we term a joining, forking, or bifurcation. These two come together at point 5. Over here, together at point 5.

Mr. Dulles.

Is that where the two ridges come together there and encase it?

Mr. Latona.

Yes, sir. From point No. 5 we pick up point No. 7, which is another one of those so-called bifurcations. One, two, three, four.

Mr. Eisenberg.

Again a ridge count?

Mr. Latona.

Ridge counting from 5 to 6. That is in the latent print. We must find the same situation in the inked print. Counting from point No. 5, the ridges which intervene, one, two, three, and then we count four, the point itself. There is the bifurcation right here.

Mr. Eisenberg.

Mr. Latona, in making these ridge counts, do you also pay attention to the so-called, let's say, geographical relation, the spacial relation of the two points?

Mr. Latona.

Very definitely. Now, it does not always follow that the so-called geographical position will coincide exactly the same. That would be caused because of variations in the pressure used when the print was made. For example, when you make a print on a fingerprint card, when the inked print was made, the print was made for the specific purpose of recording all of the ridge details. When the print was left on the paper bag, it was an incidental impression. The person was not trying to leave a print. In fact, he probably did not even know he left one. So the pressure which is left, or the position of the finger when it made the print, will be a little different. Accordingly the geographical area of the points themselves will not always coincide. But they will be in the general position the same.

Mr. Eisenberg.

Mr. Latona, without going into detail, there are some apparent dissimilarities on the two sides of that chart. Can you explain why there should be apparent dissimilarities?

Mr. Latona.

The dissimilarities as such are caused by the type of material on which the print was left, because of the pressure, because of the amount of material which is on the finger when it left the print. They would not always be exactly the same. Here again there appears a material difference in the sense there is a difference in coloration. This is because of the fact that the contrast in the latent print is not as sharp as it is in the inked impression, which is a definite black on white, whereas here we have more or less a brown on a lighter brown.

Mr. Eisenberg.

Now, Mr. Latona, when you find an apparent dissimilarity between an inked and a latent print, how do you know that it is caused by absorption of the surface upon which the latent print is placed, or by failure of the finger to exude material, rather than by the fact that you have a different fingerprint?

Mr. Latona.

That is simply by sheer experience.

Mr. Eisenberg.

Would you say, therefore, that the identification of a fingerprint is a task which calls for an expert interpretation, as opposed to a simple point-by-point laying-out which a layman could do?

Mr. Latona.

Very definitely so; yes.

……

Mr. Dulles.

These, I understand, are the particular distinguishing points, the points that you would look for to determine whether the latent print— —

Mr. Latona.

Not so much the looking for the points, as to finding points having a relationship to each other. It is the relation that is the important thing, not the point itself. In other words, all of us would have to a certain extent these points.

Mr. Dulles.

They have to be in the same relation to each other.

Mr. Latona.

That is correct. For example, on the illustration I have here— —

Mr. Eisenberg.

This is an illustration on the blackboard.

Mr. Latona.

The mere fact that this is an ending ridge and bifurcation and another ending ridge and a dot in themselves mean nothing. This is a type of pattern which is referred to as a loop, which is very common. These comprise approximately 65% of pattern types. It has four ridge counts, for example. You can find hundreds of thousands and millions of four-count loops. But you would not find but one loop having an arrangement of these characteristics in the relation that they have. For example, the enclosure is related to this ending ridge. This ending ridge is related by one ridge removed from the dot. This bifurcation is next to the so-called core which is formed by a red, the ending ridge.

The points themselves are common. The most common type of points are the ending ridge and the bifurcation. Those are the two points we have covered so far.

Mr. Eisenberg.

Mr. Latona, I see that you have marked nine characteristics on your chart. Are these all the characteristics which you were able to find— —

Mr. Latona.

On this particular chart; yes. They were the only ones that bore actually, there is still one more characteristic—there could have been 10.

Mr. Eisenberg.

Now, is there any minimum number of points that has to be found in order to make an identification, in your opinion?

Mr. Latona.

No; in my opinion, there are no number of points which are a requirement. Now, there is a general belief among lots of fingerprint people that a certain number of points are required. It is my opinion that this is an erroneous assumption that they have taken, because of the fact that here in the United States a person that qualifies in court as an expert has the right merely to voice an opinion as to whether two prints were made by the same finger or not made. There are no requirements: there is no standard by which a person can say that a certain number of points are required—primarily because of the fact that there is such a wide variance in the experience of men who qualify as fingerprint experts.

Mr. Eisenberg.

Mr. Latona, you said that not all experts are in agreement on this subject. Is there any substantial body of expert opinion that holds to a minimum number of points, let's say, 12?

Mr. Latona.

In the United States, to my knowledge, I know of no group or body that subscribes to a particular number. Now, quite frequently some of these departments will maintain a standard for themselves, by virtue of the fact that they will say, "Before we will make an identification, we must find a minimum of 12 points of similarity."

I am quite certain that the reason for that is simply to avoid the possibility of making an erroneous identification. Now, why they have picked 12—I believe that that 12-point business originated because of a certain article which was written by a French fingerprint examiner by the name of Edmond Locard back in 1917, I think—there was a publication to the effect that in his opinion where there were 12 points of similarity, there was no chance of making an erroneous identification. If there were less than 12, he voiced the conclusion that the chances would increase as to finding duplicate prints.

Now, today we in the FBI do not subscribe to that theory at all. We simply say this: we have confidence in our experts to the extent that regardless of the number of points, if the expert who has been assigned to the case for purposes of making the examination gives an opinion, we will not question the number of points. We have testified—I personally have testified in court to as few as seven points of similarity.

Mr. Dulles.

But you would not on two, would you?

Mr. Latona.

No, sir; because I know that two points, even though they would not be duplicate points, could be arranged in such a fashion that it might possibly give me the impression that here are two points which appear to be the same even though they are are not.

Mr. Dulles.

But it is somewhere between two and seven—somewhere in that range?

Mr. Latona.

That is right. Where that is, I do not know. And I would not say whether I would testify to six, would I testify to five, would I refuse to testify to four.

Mr. Dulles.

You say you would—or would you?

Mr. Latona.

I don't know. That's a question I could not answer. I would have to see each case individually before I could render a conclusion.

Now, going outside of the United States, we have been approached—I mean the FBI—have been approached by other foreign experts in an attempt to set a worldwide standard of 16 characteristics, a minimum of 16, as opposed to 12, which is generally referred to by people in this country here. Now of course we would not subscribe to that at all. And I think— —

Mr. Dulles.

That would be 16 on the fingerprint of the same finger?

Mr. Latona.

That's right.

Mr. Dulles.

Obviously, if you have two fingers that would alter the number—if you had three on one and two on the other, would you consider that five?

Mr. Latona.

We would.

Now, whether the foreign experts would not, I don't know. In other words, if we were to go along with this European theory of 16 points, we would not testify to this being an identification. That is really what it would amount to. Yet to me, in my mind, there is no question that these prints here— —

Mr. Eisenberg.

Which is what exhibit?

Mr. Latona.

The enlargements in Exhibit 634 are simply reproductions of the left index fingerprint of Lee Harvey Oswald.

Representative Ford.

There is no doubt in your mind about that?

Mr. Latona.

Absolutely none at all….

Mr. Latona.

This exhibit or this item is a lift of a latent palmprint which was evidently developed with black powder.

Mr. Eisenberg.

And when did you receive this item?

Mr. Latona.

I received this item November 29, 1963.

Mr. Eisenberg.

Mr. Latona, could you describe to us what a lift is?

Mr. Latona.

A lift is merely a piece of adhesive material which is used for purposes of removing a print that has been previously developed on an object, onto the adhesive material. Then the adhesive material is placed on a hacking, in this case which happens to be the card. The adhesive material utilized here is similar to scotch tape. There are different types of lifting material. Some of them are known as opaque lifters, which are made of rubber, like a black rubber and white rubber, which has an adhesive material affixed to it, and this material is simply laid on a print which has been previously developed on an object and the full print is merely removed from the object.

Mr. Eisenberg.

When you say "the print" is removed, actually the powder— —

Mr. Latona.

The powder that adhered to the original latent print is picked off of the object.

Mr. Eisenberg.

So that the impression actually is removed?

Mr. Latona.

That is right.

Representative Ford.

Is that a recognized technique?

Mr. Latona.

Yes; it is.

Representative Ford.

In the fingerprinting business?

Mr. Latona.

It is very common, one of the most common methods of recording latent prints.

Mr. Eisenberg.

Who did you get this exhibit, this lift from?

Mr. Latona.

This lift was referred to us by the FBI Dallas office.

Mr. Eisenberg.

And were you told anything about its origin?

Mr. Latona.

We were advised that this print had been developed by the Dallas Police Department, and, as the lift itself indicates, from the underside of the gun barrel near the end of the foregrip.

Mr. Eisenberg.

Now, may I say for the record that at a subsequent point we will have the testimony of the police officer of the Dallas police who developed this print and made the lift, and I believe that the print was taken from underneath the portion of the barrel which is covered by the stock. Now, did you attempt to identify this print which shows on the lift Exhibit 637?

Mr. Latona.

Yes; I did.

Mr. Eisenberg.

Did you succeed in making identification?

Mr. Latona.

On the basis of my comparison, I did effect an identification.

Mr. Eisenberg.

And whose print was that, Mr. Latona?

Mr. Latona.

The palmprint which appears on the lift was identified by me as the right palmprint of Lee Harvey Oswald….

Mr. Dulles.

I have no further questions. Thank you very much indeed, Mr. Latona. You have been very helpful. I have learned a great deal myself.

Mr. Latona.

Thank you very much.

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